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Bunau-Varilla, Philippe

The text of a lecture before the Commercial Club...

[s.l.]

[1909?]

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THE TEXT OF A LECTURE BEFORE THE COMMERCIAL CLUB OF BOSTON,

BY

PHILIPPE BUNAU-VARILLA,

ON THE

PANAMA CANAL.

(25th of February, 1909).

Reprinted from Congressional Record, Sixtieth Congress, Second Session, Senate, Tuesday, March 2, 1909.

The Text of this lecture was introduced by Mr. Foraker, Senator from Ohio, during a speech of Mr. Teller, Senator from Colorado, on the Panama Canal. Mr. Foraker moved that it should be printed in the Record and also printed as a Senate document. The Senate so ordered. (see over.)

The text of the lecture before the Commercial Club of Boston is followed by a supplement bearing on some important points which were to form part of the lecture, but which had to be omitted for lack of time. Also, a third chapter has been appended. It is formed by extracts from testimonies given at Ancon, Canal Zone, before the Congressional Committee on Interstate and Foreign Commerce, in which facts of the highest importance are set forth. They form, so to say, a corroborative evidence of the statements made in the lecture.

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[Extract from Congressional Record, Senate, Tuesday, March 2, 1909.]

Mr. FORAKER. I have before me a report made by M. Bunau-Varilla before the Commercial Club of Boston only a few days ago, on February 25. In the course of his remarks, speaking of the foundation of the Gatun Dam, as I understand, he quotes from Colonel Goethals, in which he says:

"The rock of the upstream toe has sunk about 20 feet in height and 200 feet in length where it crosses the canal. In sinking it has squeezed out and pushed up the clay underneath."

I understand that in the construction of the Gatun dam it was provided that there should be a "toe," as it is called, constructed of stone at the base of the dam. The dam is half a mile broad, I believe, at the base, where the water is impounded. They commenced the work by constructing the toe of the dam, and when they got it 65 feet high it sunk down 20 feet for a distance of 200 feet.

Mr. BEVERIDGE. Why?

Mr. FORAKER. Because the foundation was of such a character, as he goes on to point out, that it would not sustain that weight. That seems important, Mr. President. This speech was handed me only this morning and I have been reading it as I have been sitting here in the Chamber to-day. I find it, to my mind at least, very instructive. I think the Senate and the country ought to have the benefit of it, and if the Senator does not object, I would like to have it printed in the RECORD, and will ask that it also be printed as a Senate document.

Mr. HOPKINS. Mr. President——

Mr. HALE. I ask the Senator——

Mr. TELLER. I decline to yield to the Senator from Illinois.

The VICE-PRESIDENT. The senator from Colorado declines to yield. Is there objection to the request of the Senator from Ohio [Mr. FORAKER] that the document to which he refers be printed in the RECORD and also be printed as a public document.

Mr. HOPKINS. Mr. President, I dislike very much to object, but I think that statement ought not to go into the RECORD without a counterstatement going with it. I was not aware that this——

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Mr. FORAKER. Mr. President, I do not want to take the time of the Senate away from the consideration of the deficiency appropriation bill or any other bill that is reported; certainly I do not want to delay any of these matters; but I apprehend that the question which the Senator from Colorado [Mr. TELLER] is discussing is about as important as any other that is before the Senate, and even more important.

I do not know what ought to be the determination with respect to the Panama Canal. I only know, as I stated in the Senate some days ago, that I voted for a lock type of canal with some misgiving as to the wisdom of that vote. I have had that same misgiving ever since. I tried when there was an additional report made a few days ago to dismiss from my mind any further misgiving about it; but since then I have seen a number of facts stated in the press that have caused me to recur to that same state of mind. When I read this address made by Bunau-Varilla before the Commercial Club of the city of Boston only a few days ago—I read it here in the Chamber only this afternoon—my mind again went back, without any misgiving whatever, to the state of doubt, at least, in which it was before. I fear a great mistake will be made if the construction of a lock type of canal is insisted upon; but I am not prepared to discuss that and would not ask the Senate to bear with me that I might do it at this late day in the session; but I think the Senate ought to have the benefit of what this engineer has said. All that he says he backs up, it seems to me, with data that you will find conclusive in character, and I hope the Senator from Illinois will not object to this being put in the RECORD. If he should I shall have to read it.

Mr. TELLER. I will put it in my speech.

Mr. BAILEY. Mr. President——

The VICE-PRESIDENT. Does the Senator from Colorado yield to the Senator from Texas?

Mr. TELLER. Yes.

Mr. BAILEY. I should like to ask the Senator from Ohio if that is the same person who was the first duly accredited minister from the Republic of Panama to the Government of the United States?

Mr. FORAKER. I understand he is. I do not know what his standing ought to be either as a minister or as an engineer, but I have always heard that he stands very high as an engineer throughout the world, in the estimation of men who are competent to judge. At any rate, what he says here can not do anybody any harm, and it might do some good.

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Mr. BAILEY. I do not know how much of an engineer he is, but I think he is a most accomplished diplomat, for, as I understand, he is one of the few men who has had his credentials cabled to him.

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Mr. FORAKER. I desire to say one word in answer to the Senator from Illinois [Mr. HOPKINS]. I have not offered any paper or any remark in any controversial sense. I think we ought to get all the information we can of every character in regard to this matter. It is not so important to me as it is to Senators who remain in the public service. I go out within a few days. They remain. If I were to remain here, I would get, and they ought to have, all the information obtainable, and I make the request for no reason in the world except that the Senate should have all the light it could get.

Mr. HOPKINS. In view of what the Senator from Ohio says, I shall not interpose the objection that it was my intention to make. I do not attach the importance to the speech that the Senator from Ohio does, and the criticisms I have heard made upon it satisfy me that it is entirely unreliable. But in view of the position taken by the Senator from Ohio, as I say, I shall not object to its being printed in the RECORD.

Mr. FORAKER. The Senator can do no greater service to the Senate and the country than by showing that it is unreliable. Until he or somebody else does show it is unreliable it is bound to make an impression, I think, on the minds of fair-minded men.

Mr. HOPKINS. In response to the Senator from Ohio I will say that I was not aware that this debate was to come on to-day. I have material on this subject which I think will be of interest to the Senate and the country. Had I supposed that it was to be discussed in the manner it has been presented I should have been here to present the other side.

The VICE-PRESIDENT. Will the Senator from Ohio restate his request?

Mr. TELLER. I will ask it, because I have some papers of the same kind. I have an article written by a very distinguished engineer in this country, who knows all about the canal. It is written in good temper and proper spirit. I ask that it may be printed in the RECORD in connection with the paper presented by the Senator from Ohio.

The VICE-PRESIDENT. Without objection, permission is granted.

Mr. FORAKER. I make the further request that the address delivered by M. Bunau-Varilla may be printed as a document.

The VICE-PRESIDENT. Without objection, it is so ordered.

COMMERCIAL CLUB OF BOSTON.

LECTURE OF MR. BUNAU-VARILLA

ON

THE PANAMA CANAL

(25th February, 1909.)

GENTLEMEN:

It is for the second time that the Commercial Club of Boston extends to me its gracious hospitality. The first instance was when this country had to choose between Panama and Nicaragua for the establishment of the great maritime highway of nations.

I came to America, in the beginning of 1901, to develop publicly the scientific arguments, which in my opinion demonstrated the impossibility of the Nicaragua solution.

After the lecture which I gave in this Club, Mr. Lucius Tuttle, who presided over the meeting, expressed, in the following words, the impression it had made upon his mind. "I see "that with the Nicaragua project we have opened the switch "on the wrong track. It leads to a precipice—we must stop, "go back and take the other track."

This is just what happened. I need not recite the events which seem more to belong to romance than to reality, and which finally led to the defeat of the Nicaragua solution; the splendid fight in the Senate by that great citizen Senator Mark Hanna, whom I had met through my friend Governor Myron T. Herrick of Cleveland and whom I had succeeded in making the firmest believer in the Panama solution; then the secession of Panama, the formation of a new republic which

INTENTIONAL SECOND EXPOSURE

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entrusted me as Minister Plenipotentiary, the representation before the United States and all the nations of the world, of its vital interests which were those of the construction of the canal over its predestined territory.

Tomorrow there will be five years since I exchanged with your great statesman John Hay the ratifications of the treaty by which the Panama Canal, like the Phœnix of the fable, was to be born out of its own ashes.

And today I come again before you as I did eight years ago to tell you, and through you the people of the United States, that the switch has been opened on a wrong track, that it leads to a precipice, that it is time to stop, to go back and to follow the other track.

The essential question at issue is that of the stability of the Gatun Dam.

You know in its general lines the project actually under construction. It consists in creating, on both sides of the continental backbone, a great lake by damming near the oceans the valleys of the two rivers which come from the Cordillera. It consists in opening the continental backbone at such a level as the two lakes will freely communicate between each other. It consists finally in establishing, near each of the two dams, flights of locks which will allow ships to rise from the level of one ocean to that of the lakes, say 85 feet, and after crossing the lakes to descend from the level of the lakes down to the level of the other ocean.

Of course each of these two dams is essential. If it breaks and disappears under the pressure of the water and its torrential escape, the essential element of the canal will also have disappeared. There will not be any more possibility of passing a ship than there is today.

This conception of the canal at Panama is the child of the conception of Nicaragua : a big lake suspended above the oceans at a level of 100 feet, more or less, to which ships will

have access by means of these steps for ships, which are called locks.

It came into the world in 1879 during the International Congress called by Mr. de Lesseps, and where the different solutions of the Isthmian Canal clashed.

Mr. Godin de Lepinay was its inventor. Nobody then thought of but one process for excavating the canal, the digging in the dry by steam shovels and trains. Mr. Godin de Lepinay knew very well of the difficulties of the tropics and he proposed the lake and lock system, which is actually in course of execution. He founded the justification of his project precisely on the very same arguments which are today invoked in its favor against the sea-level plan, that is against the narrow canal which is freely open on the Atlantic, which has no tides, and which is closed on the Pacific side by tide locks in order to prevent the tidal variation of level of this ocean to cause currents which would be objectionable in a narrow canal.

Godin de Lepinay fixed 24 meters above the oceans for the level of the lakes, say 79 feet. He proposed the location of Gatun for the dam on the Atlantic, but he at the same time gave warnings of the possible danger of its construction.

At the very instant of its birth in the engineering mind in 1879 the Gatun dam was denounced by him who had conceived it as dangerous.

The actual lock and lake plan adopted by the minority of the Consulting Board in January 1906, textually reproduced the proposition of Godin de Lepinay of 1879. The level of the lake was fixed at 85 feet and the Gatun location for the dam was adopted on the Atlantic side, when on the other hand the La Boca location was selected for the dam on the Pacific side.

Had anything happened between 1879 and 1906, which could have been invoked in favor of the stability of a dam at Gatun ?

Nothing! On the contrary. The intimate knowledge of the formation of the Isthmus, of the character of its soil which resulted from a battle of more than seven years against nature, during which 72,000,000 cubic yards were excavated in the middle of a constant epidemic of yellow fever, demonstrated that a dam at Gatun would be in the worst condition an engineer could dream of.

The great difficulty we had to contend with was precisely the particularly slippery and treacherous nature of the soft clay resulting from the weathering of the solid mass of the Isthmus, brought by the waters in infinitesimal particles and deposited all along the canal. It was the most difficult material and the most slippery that could be imagined.

During many months I was in doubt if it was really possible to dig through that mass of clay, as slippery as soap, which formed the superior strata of the Culebra cut.

Nobody will ever know what efforts, what anxiety it has cost us to pierce and to remove this mass of soft ground and to reach the solid core of the Culebra cut in which the actual workers can establish solid tracks on a firm soil.

The conditions we found on the highest point of the canal cut, at Culebra, are the same at the lowest point, at Gatun, but there the accumulation of this soft and slippery material is below the level of the ocean; it is in the subsoil.

I met it when I opened the canal in that region. The clay, which the buckets of the dredges attacked in the bottom of the canal, was so sticky and plastic that very often it moulded itself into the buckets in such a way as to refuse to fall down; the dredges had to be stopped and men placed all along the bucket chain to dig with shovels into the buckets, and to empty them.

This is why I looked upon, and I am looking with so much concern upon a dam at Gatun seated upon these slippery strata.

The very first time I heard of a revival of the idea of a dam at Gatun was by a note from Mr. Alfred Noble asking my opinion about constructing a lake, dam and lock canal with dams at Gatun and at La Boca. It was on the eve of my departure for France, five years ago after exchanging with Mr. Hay the ratifications of the treaty under which the canal is now constructed, the so-called Hay-Bunau-Varilla treaty.

I replied offhand to Mr. Noble that there was no probability of finding foundations at either place, but especially at Gatun.

The events have justified this opinion, as soundings have shown that bedrock at Gatun was about 260 feet below sea level and because they have also revealed that above the bedrock exists an enormous mass of blue clay which can under no pretense possible be called legitimately a foundation even for an earth dam.

When the minority of the International Consulting Board revived in January, 1906, the old plan (lake, dam and lock) of Godin de Lépinay, already deemed an inadequate solution in 1879 and adopted the location at Gatun for a dam in spite of the warnings of the creator of this conception himself, the majority of the Consulting Board protested against such a dangerous experiment.

I protested also in a public letter to President Roosevelt, dated March 5th 1906, which was reproduced by the daily papers, against the instability of the huge Gatun dam. As the method of construction adopted was an entirely new one, which I had described to the Consulting Board at the beginning of its works, as was registered in its report (page 213). I felt bound to reject all future responsibility and "to expressly "disapprove, from a scientific standpoint, the use of that "method, very good for a small, low and temporary dam, "highly dangerous for a huge dam of more than 20,000,000 "cubic yards in volume in a country frequently shaken by "earthquakes."

At the very beginning of the construction of the dam at La Boca by Colonel Goethals, the difficulty of carrying out the plan and the method of construction was such that the location adopted was abandoned for that of Miraflores some miles higher up the valley.

This necessity of abandoning the La Boca location was reported on December 9th, 1907 by the Chief Engineer of the Canal, Colonel Goethals. The change was approved by the President on December 20th and published in the Canal Record in the number of December 25th following.

It was nature which at this moment added its first warning to that of men.

Nature gave a second and recent warning when the construction of the Gatun dam began last year.

The first work undertaken was to construct along the foot of the dam on the lake side an embankment of stone, the part of which was to sustain the earth which will constitute the body proper of the dam.

The Canal Record of November 11th, 1908, stated that this embankment (called also the rock toe of the dam) was about completed at a height of 60 feet above sea level. But on the 25th November a cablegram from Colonel Goethals announced that it had given way at the crossing of the old french canal and that it had lost 20 feet of its height on a distance of 200 feet.

I knew what ground was there at the bottom of the old canal, for I opened it myself, and I expected the first warning of nature would come in that neighborhood. It therefore did not surprise me in the least. I considered it an ominous but providential Mene, Mene, Tekel, Upharsin written by nature on the bottom of the future Gatun dam. I gave my views to the Herald and to the Figaro in Paris and they were published on the 12th of December in New York.

Soon after, as you know, it was made public that the President elect, Mr. Taft, intended to go to the Isthmus with a body of consulting engineers and that Colonel Goethals had been invited to make a reply to me.

As you know also the results of this consultation was entirely favorable to the Gatun dam. It was found to be not only safe, but exceedingly so and therefore it was advised to reduce by 20 feet the height of the dam above the level of the lake, which height above the water had been originally fixed at 50 feet, in order to form a margin of security against any possible contingency such as a tidal wave in the lake due to an earthquake or a settling of the dam similar to that which happened to the rock toe.

It was formally denied that this modification had been inspired by the desire of diminishing the weight of the dam upon its base of soft clay. The reason advanced was the desire to make a little economy in the structure.

Gentlemen, if in such a grave matter a jocular reminiscence could be admitted, I would tell you the story of that Spanish tailor who one day saw a very tall customer enter his shop and ask for a cape. He realized that he had none in the store for such a tall man. However, he took the longest cape he had and put it on the shoulders of his client. Before the purchaser had time to examine if the cape fitted him, the tailor had jumped to his scissors and putting himself in the attitude of cutting the lower part of the cape, he said: "This cape is decidedly too long for you. I am going to cut "it a little." "Oh," answered the client, "don't cut it, it is "not too long, it is all right so," and he bought it and went. I hope you will excuse this jocular story, but I cannot help remembering it when I speak of that astonishing decision of modifying the design of an earth dam on account of the excess of its stability.

This is the first time in my life of engineer that I ever heard of an excess of stability for an earth dam.

But, however, the question has been settled, the Government has spoken its last word. It has been said to be so final that any further discussion would have to be ascribed to opposition against any canal.

The New York Tribune, which generally expresses the views of the administration said in an editorial : " We have " no idea that all Americans, or all expert engineers, or all sin- " cere friends of the canal, will be convinced by this report " and will be persuaded that the sea level plan is not the best. " But at least it should be possible for reasonable men to " credit these expert engineers with professional acumen and " prudence and with entire sincerity and to place reliance " on the judgment of the administration which is responsible " for the great work and which must bear the blame of failure " or disaster if any should befall it. It seems to us high time " for dissension and doubt to give place to a cordial support " of the canal enterprise and to a cheerful confidence in its " success."

These are very wise thoughts and I have meditated upon them. They should be listened to and obeyed if the question was a mere question of more or less perfection, of more or less expenditure, if it was simply one of those questions of philosophy, of economics, of politics, which once settled, even badly settled, must be dismissed from public discussion at least for the time being.

But this question is different ; it is a question of life or death for this work which humanity is longing for since centuries. If, as I think, the fact is written in advance, that the Gatun dam will give way, can I give it a cordial support and enjoy a cheerful confidence in its success ? No, that is impossible. It is also impossible to stay silent until I have exhausted all possible means to drag the truth out of her well and to show

her. It seems to me that I would be a treacherous friend of this great country, a double faced flatterer of President Roosevelt if I acted so.

I may lose the friendship of this great American and also his confidence. I shall have lost something to which I attach the highest value, something of which I am very proud.

Nothing will deter me however from doing my duty, and as Colonel Picquart said in the most trying phase of the Dreyfus affair " I shall not go to the grave with that burden on the " heart."

I propose to lay bare before you all the direct and circumstantial evidence which prove that the Gatun dam is an unstable structure and that the experts who recommended it have made and are making a terrible mistake. I shall speak openly without the slightest shadow of bitterness against any of these prominent engineers whom I individually respect. If I confront facts with opinions it is simply in order to generate by their friction the spark which will throw light on that obscure question.

As I told you the first man who thought of erecting a dam at Gatun, Godin de Lepinay in 1879, was also the first man who doubted its possibility. He never spoke of it later on.

As I told you already also, the dredging of the bottom of the canal brought to light in 1885 this sticky, plastic, soft, slippery blue clay which will underlie the dam to a great depth on more than one-third part of its length.

As I told you, this personal experience as well as the general and practical knowledge of the formation of the Isthmus led me to write to Mr. Noble in the first days of March, 1904, that no foundations for a dam would be found at Gatun.

These are disinterested testimonies before there were any talks of erecting a dam at Gatun. They were not influenced therefore by any passion generated by the heat of a technical controversy.

In January, 1906, the minority of the consulting board recommended a dam at Gatun and another, or rather a couple of others, on the shores of the Pacific, the principal one being at La Boca, across the mouth of the Rio Grande river. The pressure exerted on the ground at the base by the embankment which constitutes the dam was declared in their report to be six and a half tons per square foot at Gatun. The minority report was signed by M. M. Alfred Noble, Henry L. Abbot, Frederick P. Stearns, Joseph Ripley and Isham Randolph.

The majority of the board was formed by Gen. W. Davis, Messrs. Wm. Barclay Parson, Wm. H. Burr, Wm. Henry Hunter (named by the English Government), Ad. Guerard (named by the French Government), Eugene Tincauzer (named by the German Government), J. W. Welcker (named by the Dutch Government), E. Quellennec, Chief Engineer of the Suez Canal.

The majority said textually on the La Boca and Gatun dams: "The board is therefore of the opinion that the existence of "such costly facilities for the world's commerce should not "depend upon such reservoirs held by earth embankments "resting literally upon mud foundations or those of even sand "and gravel. *The Board is unqualifiedly of opinion that no "such vast and doubtful experiments should be indulged in.*"

The minority in its report defended the earth embankments on the ground that no seepage could occur owing to the nature of the soil of the embankment and that of the subsoil. And in this it was correct, provided both would remain in place. Nothing was said to relieve the mind of the fear that the softness of the foundation might generate movements of mass infinitely more dangerous

than percolation because they are bound to leave large fissures into which water will immediately penetrate in great quantities.

As soon as the project was adopted I denounced in a public letter the unstability of the huge Gatun dam as I said already. But not being willing to bring again the foundation question, which I had opened in 1904 with Mr. Noble and which had been dealt with most completely in the majority report, I further indicated the peril of fissuration by slight earthquakes of the earth dam which means an immediate washout of the dam. This was not a pure hypothesis. In 1882 all the surface of the earth in Colon, that is, in the immediate neighborhood of Gatun, was fissurated by an earthquake and the record of this ominous fact is in the Isthmian Canal Commission's report of 1901.

Such were the opinions brought forward by the various parties engaged in the contest and which were: the minority defending the lake and lock plan which might be termed the third class solution, the majority defending the narrow sea level canal with tide locks on the Pacific, which might be called the second class solution, and myself defending what might be called the first class solution, the perfectly free, open, wide, deep passage between the oceans entirely freed from any artificial structures such as locks and dams. This is what I called the "Straits of Panama" in order to distinguish it from the narrow, tide locked "Sea Level Canal."

Now if the minority was right or wrong in its conclusions the subsequent facts must show. If it was accidentally wrong on one point and right on the generality this can be condoned. But if a continuous series of facts demonstrate that a general error pervades all its works, then the greatest caution is required and just suspicion is cast on its views on a point for which a correct judgment is essential because it commands the whole situation.

This will be what might be called the circumstantial evidence against the Gatun dam after enumerating the independent testimonies anterior to any project of a dam at Gatun.

First Error of the Minority. The principal argument in favor of adopting the third class solution, the lake, dam and lock plan, was its reduced cost. It was set forth at $139,000,000. It is now fixed at $297,000,000 and it is not yet finished. This figure excludes all the items excluded from the original evaluation of $139,000,000. If we include them it reaches $375,000,000.

Second Error of the Minority. In fixing the dimensions of the locks for future increase of ships they decided for their length to adopt 900 feet and for their width 95 feet. In fixing these figures they said it was not necessary to adopt respectively 1000 feet and 100 feet, as the majority did for its tide lock in the sea level canal, because "no "one would expect to provide in any commercial or military con- "struction for needs at the end of the present century." One century has not lapsed since 1906 and, however, the dimensions of 900 by 95 have not only been found already too small but even those of 100 by 1000 feet have been found so. The present rectified dimension adopted are 110 by 1000 feet.

Third Error of the Minority. This error is also shared by the majority. The great question which had really inspired in Godin de Lepinay the idea of a lake, dam and a lock canal in 1879 was the extreme difficulty and cost of excavation by steam-shovels and trains under the conditions created by the terrible rainfalls in the tropics. His aim was simply to reduce the amount of excavation by raising the level of the passage

through the backbone of the Cordillera. But since a new method of excavating the rock was started which absolutely eliminates the difficulties of cost and of time. It consists in dredging the rock under water after having broken it in pieces as large as a man's head. I started this new principle in 1885 on the canal with a new method of mining. Later on the method was developed on the Suez Canal by the substitution of mechanical concussion to dynamite explosion. It is now perfected and gives results which are astonishing as to celerity and economy in the largest public works on earth, such as the Suez Canal and the Manchester Ship Canal.

In 1901 the Isthmian Canal Commission had fixed the removal of rock under water at $4.75 a cubic yard.

I showed to the Consulting Board that it was now demonstrated to be infinitely lower, but they still fixed the price at $2.50 for the removing of one cubic yard of rock under water when the cost of ordinary dredging was placed at fifteen cents.

These two prices show that the preliminary operation of breaking one cubic yard of rock was fixed at two dollars thirty-five cents.

One year and a half later before the Institution of Civil Engineers of London, in June, 1907, special and official reports have shown that the actual cost of that operation had been in reality twenty cents a cubic yard in the Suez Canal and in the harbour of Blyth and twelve and one half cents in the Manchester Ship Canal.

This third error of the Consulting Board, in fixing a price more than eleven times too great if the Suez Canal is taken as the standard and more than eighteen times too great if the Manchester Ship Canal is taken as the standard, has entirely thrown out of consideration the only economical and powerful method by which the canal can be constructed, not only as a narrow canal at sea level, but as a veritable wide and deep Straits. It is this deplorable error which has led the United States into the wrong way and enticed them to take the most

inferior, the third class solution, when the perfect, the first class solution, could be obtained at a less cost.

FOURTH ERROR OF THE MINORITY. As we have seen, they recommended the erection of a dam of earth at La Boca on the Pacific. Their sincere but erroneous conviction was such that it had passed into the minds of the engineers in charge of the construction on the Isthmus.

President Roosevelt on his return from the Isthmus wrote in his message of December 17, 1906: "La Boca dam offers "no particular problem, the bottom material being so good "that there is a practical certainty not merely as to what can "be achieved, but as to the time of achievement."

The Secretary of War, Mr. Taft visited the Isthmus some months later in the spring of 1907. He was accompanied by two of the engineers who had signed the lake, dam and lock plan, Messrs. Noble and Stearns and by a third engineer of considerable reputation, Mr. Freeman of Rhode Island, who was also invited to add his advice to that of the former members of the minority of the Consulting Board.

They declared on their return with Mr. Taft, that everything was all right and that the La Boca dam was a certain success, just as the Board which recently came back with Mr. Taft, declared that the Gatun dam was perfect. They did not, however, go as far as saying, as the recent Board was reported as having said about the Gatun dam, that it was unnecessarily strong and had to be modified for that reason. (The board which went with Mr. Taft this year consisted of six members, three of whom had already been associated with the present plan—Messrs. Stearns and Randolph who signed it and Mr. Freeman who approved it a year later (1)).

The Board of 1907, that is, Messrs. Noble, Stearns and

(1) A seventh member was added at the last moment to the six first ones.

Freeman reported about the La Boca dam as follows (Canal Record of Wednesday, December 25th, 1907):

"The borings showed a so-called mud in the swampy sec- "tion having a depth of 8 to 10 feet. This material is firmer "than we had expected and at the time of our visit, about two "days after it had been flooded by spring tides, it could be "walked on in most places.

"*For the dam construction we do not think it will be "necessary to remove the soft material at either of these "places.* (Sosa Corozal and Sosa San Juan). The very softest "material will either be displaced or consolidated by the "material disposed on it. We do not think the amount dis- "placed beneath the impervious portion of the embankment "will be great and if compressed in place the material will be "impervious."

Thus spoke in 1907 the experts who had signed the plan in 1906 and the new expert, Mr. Freeman, who had joined them for the purpose of verification.

Now, let us look at the facts as described by the Colonel Goethals in the report of December 1907 to the Secretary of War, which was also inserted in the Canal Record of December 25th, 1907.

"To construct the dam according to these views, trestles "were built along the toes of the Sosa Corozal dam from which "to dump material from the Culebra cut. The trestles failed "after the dumping of the material from them began and the "material overlying the rock moved laterally carrying the "superimposed mass with it, the dumps flattening out until "the side slopes where about one on twelve or even less.

"In places this lateral motion continued for two weeks after "dumping had stopped, the ground on either side of, and at "some distance from, the dump was forced up forming mounds "of mud, the crests of which gradually approached the level "of the top of the dump proper. After an equilibrium was "established between the dump and the adjacent mounds, the

" hump or wave would again move out when the track was " shifted towards it accompanied by a sudden vertical settling " of the track of six to ten feet where loaded trains were ap- " plied. It was thought that if the trestle were lower better " results might be obtained but with the new trestle only " eight feet above the surface of the ground and the piles " driven to the rock similar failures followed.

" When the difficulties on the east trestle developed an in- " vestigation by boring and test pit was made to determine the " character of the material overlying the rock. It was found " to be for the greater part an unctuous blue clay without grit " possessing but little supporting power, instead of the stiff " clay as indicated on the existing profile.

" The investigation clearly demonstrated that *the construc-* " *tion of a dam which would remain after the lake is filled can* " *be accomplished only by the removal of all the materials* " *overlying the rock.* * * * Investigation of the founda- " tions of the Sosa San Juan dam showed that the material is " the same: the difficulties to be encountered will be greater " because of the river."

Various plans were submitted by Colonel Goethals in view of the impossibility of building, as it was projected, the dam planned by the minority of the Consulting Board and recommended a second time by a commission formed of two members of that minority and Mr. Freeman.

We have now seen that in four different occasions the opinions expressed by the minority of the Consulting Board have been controverted by facts. 1st: The estimates of the cost of the plan proposed is fixed to-day at more than twice the amount originally fixed, 2nd: Vessels both military and commercial, are now building which could not enter the locks, which three years ago seemed to the Board large enough to satisfy all future needs, except those to come at the end of the

present century. 3rd: The cost of transforming rock into dredgable matter was fixed three years ago at a price which one and a half years later was shown to be eleven times too great in two instances and eighteen times too great in the third one. 4th. One of the two great dams to be erected, the one considered to be the most easy of execution and the most certain of stability, was found impossible at the place chosen and by the method recommended.

These manifest and undeniable errors of judgment on the four essential points examined should induce, a very careful revision of the opinions expressed on the fifth essential point: on the Gatun dam.

If an error similar to the four others already demonstrated occurs a catastrophe without precedent in history will follow. The result of ten years of arduous work, the result of an expense of four hundred million dollars spent by this government and of two hundred and fifty million dollars spent by the French share and bondholders of the Old Panama Company will be anihilated in a quarter of an hour without counting the probable destruction of the town of Colon and the possible annihilation of a whole fleet of men of war which will be stranded and imprisoned for years if the Gatun dam collapses during its stay in the Gatun Lake.

Cassandra had received from the gods the privilege of seeing in advance the calamities which menaced humanity but they had refused her the privilege of being listened to.

The part of a Cassandra is a disagreeable one and the victorious "I told you so" is a very poor compensation to the years of suspicion and ill-will which must be accepted before.

But I have received, I can assure you, no privilege from any god whatever, and if I say that this catastrophe is bound to come, it is simply the result of the rational method of in-

duction which Bacon gave to the world and which has transformed humanity.

There are already facts enough to obtain truth by induction from them.

The two first facts are those I already spoke of. (A) the doubt cast, by Godin de L'epinay in 1879 on the possibility of its construction, that is by the man himself who conceived it and at the very moment he made his conception public. (B) the spontaneous statement I wrote to Mr. Noble in 1904 about the lack of foundations at this place. These testimonies were unbiased by any sentiments of bad or good will towards a project which was only to be formulated later in 1905. Though they are expressions of opinion, they may be retained as facts because both were the result of knowledge acquired from a series of experimental facts belonging to the Panama Isthmus proper.

We come now to the facts relating to the Gatun dam proper.

At the beginning of the second week of December last I read in a New York paper of November 26th, which had just arrived in Paris, the following cablegram of Colonel Goethals about a slide having occurred in the stone embankment which was to form the retaining wall of the earth of the Gatun dam. It read :

" Reported injury consists of slip in rock pile intended to
" form south toe of Gatun dam and has no effect on body of struc-
" ture which is not yet in place. Part of rock pile about 200
" feet in length crossing old French canal has been slipping
" northward from time to time and slipped again on Friday,
" (November 20th) due to excessive rains lowering crest
" of pile about 20 feet. Slip of this kind not new, occurring
" frequently all along the line. Present slip of no consequence and of character to be anticipated in such work."

This reassuring telegram did not reassure me. I knew of what the bottom of the French canal consisted. I did not hesitate to think that the accident was a providential lesson of nature showing in advance what was bound to be the fate of the Gatun dam at the end. I could read, though evidently the writer had not meant it, in the very telegram of of Colonel Goethals the real prophecy of what will take place later on : "Slips of this kind to be anticipated in such work."

Yes indeed, they are and it is precisely the reason why a dam of earth under this constant menace is so dangerous, so sure to succumb, so sure to annihilate the object of this magnificent enterprise, the ambition of our age.

What would be the result of a similar settling of the dam if it occurred when the dam is built ? As you know, the normal levels of the waters are to be 85 feet above the sea level. It is admitted that the level in great floods will rise to 87 feet, and in droughts will be only 82 feet.

The crest of the dam was fixed originally at 135 feet leaving a margin of safety of 48 feet above the maximum level.

After the return of the Board of Engineers who accompanied the President-Elect to the Isthmus it has been *announced that they found the dam unnecessarily high and strong* and that the crest would be accordingly lowered 20 feet. This will reduce the proposed margin of safety to 28 feet.

Now, if the embankment of stone sixty feet high has lost through the slip of the 20th of November last twenty feet of its height, say one-third ; the dam itself, 115 feet high, would lose under similar circumstances 35 feet. It would be reduced to an altitude of 80 feet above the sea, say seven feet below the maximum level of the water, five feet below the normal level and two feet below the minimum level. In a few minutes the dam would have disappeared.

Is the eventuality impossible to conceive ? By no means.

It is on the contrary in the logical order of things if you examine the causes of the slip of the rock embankment.

The cause was the softness of the blue clay on which it was seated, its incapacity of supporting a load of any consequence.

The load resulting from the superimposed rock embankment was relatively slight compared to what it will have to stand when the dam will be established.

A rock embankment forms a sort of homogeneous and solidarized mass owing to the friction of one element on another. This insures a relatively equal repartition of the total weight on the base.

As the rock embankment is narrow at the top and wide at the base, the pressure per unit of surface on the natural ground will be about half what it would be if it consisted of a mass having the same base with vertical sides. On the other hand, in a stone embankment about one-half of the mass only is rock, the other half is formed by the hollow spaces, between the pieces of rock. On the other side a mass sixty feet high weighs about half what it would if 115 feet high, all other conditions being equal.

For these different reasons the pressure of the central mass of the dam on the ground will be about eight times greater than the pressure exerted by the rock toe and which caused the loss of one-third of its height.

It is therefore by no means inconceivable that under a pressure about eight times greater, the soft clay will slide away from under the dam much more than it did during what may be called the experimental slip of the rock toe.

This logical induction from the slip of the 20th of November is based on the assumption that it resulted from the lack of supporting power of the blue clay. You have a right to demand a demonstration of that assumption because if it is due to another cause the argument is erroneous and misleading.

After the New York Herald published on the 12th of December the statement I had made on the previous day about the certainty of the impending destruction of the Gatun dam, the answer was given out in the public press apparently from responsible sources that the slip *was expected and even desired.* It was explained that the cause of it was the light silt deposited upon the bottom of the old French canal. If it had been so the rock embankment would *have slipped upon the bottom of the canal and not through the bottom into the ground below.* This explanation would have acquitted the soft clay of any responsibility in the accident.

To support this hypothesis was the statement inserted in page 11 of the Annual Report of the Isthmian Canal Commission and signed by Colonel Goethals August 25th, 1908. Speaking of the soundings through the ground below the Gatun dam it said: "The material encountered is of such nature as to be " amply strong for supporting the proposed structure."

But Colonel Goethals is an officer and a gentleman and he is not capable of modifying the facts even if they controvert his opinion. In the answer which he was requested to make to me and which was published on the 10th of January last he said:

"The rock of the upstream toe has sunk about twenty feet " in height and 200 feet in length where it crosses the canal. " *In sinking it has squeezed out and pushed up the clay under-* " *neath.*"

This frank and open statement of fact shows that the rock pile has really sunk through the bottom of the canal into the soft clay. It acquits the silt and brings all the responsibility on the lack of supporting power of the clay.

If you remember what I extracted a little while ago from

Colonel Goethals' report about the impossibilities described at the La Boca dam you will see that the description he gives of the accident of the rock toe entirely resembles what he said about the La Boca dam. The two accidents were to be identical because the causes are identical at the two extremities of the canal.

But Colonel Goethals in his answer to me acknowledges also the presence of the blue clay and its lack of supporting power, thereby entirely withdrawing its assertion of August 25th, 1908, about the strength of the material below the dam. He says:

"The stratum of blue clay which Mr. Bunau-Varilla men-
"tions as a danger at Gatun exists chiefly into deep gorges
"in the rock which are crossed at about right angles by the
"axis of the dams and, where crossed, are about 1900 feet and
"950 feet wide respectively at sea level. * * * It is im-
"permeable to water and *requires only to be kept in place to*
"*form a reliable foundation* for an earth dam of suitable cross
"section."

Colonel Goethals explains how, by extending the foot of the dam he hopes to counterbalance the tendency of the clay to escape from under the dam.

Now, Gentlemen, it is a matter of common sense. Is this any more admissible? Can the meaning of the words be changed? What is a foundation: It is a mass of ground on which a structure is to be erected. What part has it to play? Only one part, that is to keep the structure in place. Is this not the obvious and explicit condemnation of a given work when the chief engineer declares that the structure must be so devised as to keep the foundations in place? Does this not appear as a reversal of all the elementary notions of gravity and of natural forces? But a castle in the air could be projected on such a principle.

It would be possible and stable if we could keep the air in place by lateral wings of the castle.

No, the air will escape from under the wings as the soft clay will escape from under the body of the Gatun dam and from under its accessories, because it is a fluid matter like the air, though at the extreme limit of fluidity.

You may retard its movements, but they will take place at a given moment and at that moment the Gatun dam will have lived.

If we wish the connection between the oceans to be established we must not, as the majority of the Consulting Board said three years ago, indulge in dangerous experiments.

But now we have gone farther than that, the facts have shown the practical impossibility of the earth dams and we are driven into the land of imaginary engineering.

The Gatun dam will be destroyed by the subsidence below the level of the water of its crest which is 374 feet thick at that level. Its huge thickness of one half mile at the base will not protect it.

But there is another mode of death to which it is exposed, even if the movements of the clay below would not bring its crest below the level of the lake.

You have often seen while walking in the country these walls fissured and cracked. When you see that it is due to the fact that a part of the wall is seated on firm ground while the other is seated on soft ground. They do not settle together and an unavoidable opening ensues.

Now you have seen, by what Colonel Goethal says, that the blue clay existed chiefly in two places respectively, 1900 and 950 feet wide. The total length of the dam is 7700 feet. These figures show that at four different places at least there will be a sudden change in the resistance of the subground. At these four places crevices will be opened through the body of the dam through which the water will flow. The opening through an earth dam need not be great to entail the immediate destruction. A fissure of a fraction of an inch

suffices, when there is behind that fissure a lake of 170 square miles surface and a head of 85 feet of water, that is to say, a pressure of about 34 pounds to the square inch.

Now, gentlemen, I brought before you the facts which demonstrate that the Gatun dam cannot and will not stand. This is the truth to which the induction from facts leads, I think.

But I have not come here as a prophet of evil to persuade that the way is closed and that we must abandon the hope of uniting the oceans.

On the contrary what I wish to say is that the solution of this great mystery of nature is at our disposition, and that we can obtain for less expenditure than remains to be spent on the lock canal with a dam at Gatun the free open junction between the oceans which I called the "Straits of Panama."

The Difference Between the So-Called Sea Level Canal and the So-Called Straits of Panama.

The word "sea level canal" describes the canal which Mr. de Lesseps started to build in 1881 and which was at that time thought to be the extreme limit of human possibility, if not beyond.

It was not then what humanity had dreamed of, what Mr. de Lesseps had dreamed of, but it was the next best thing.

What had been the dream of the centuries was the wide open communication between the oceans, free from any works of art.

The sea level canal of Mr. de Lesseps was a narrow canal just sufficient for one ship to pass, 72 feet wide at the bottom, 30 feet deep, open on the Atlantic Ocean but closed on the Pacific Ocean by tide locks. Why? Because though the two oceans have the same average mean level; one, the Atlantic, has

no tides at Colon and the other, the Pacific, had tides 10 feet above and 10 feet below mean level. As the canal is in a very wet country it will have to carry to the sea the water of some rivers and it was not found possible to admit the combined currents due to the fresh waters and those due to the tides without troubling navigation.

To remove all these objections it is necessary to give 500 feet width at the bottom, 600 feet at the average water level and 45 feet at the lowest stages of the tides.

Such a canal was absolutely beyond the limits of possibility twenty-five years ago because of the enormous excavation it entails, six hundred millions cubic yards, and because of the impossibility of excavating then otherwise than by steam-shovels and trains.

In September 1905 at the outset of the studies of the International Consulting Board, I developed before this Board the methods by which this magnificent scheme may be said to have passed from the land of the imagination to that of the realization.

The Consulting Board refused to admit the demonstration resulting from the new methods of works and the most recent conquests of engineering. It remained faithful to the old principles of excavation, the excavation by steam shovels and the transportation by trains of the spoils to the dumps. The Consulting Board refused to admit that engineering had progressed since 1879.

The same causes producing the same results, the conclusions reached in 1906 were exactly those reached in 1879. The majority of the International Consulting Board adopted like that of the International Congress of 1879 the so-called narrow, tide-locked sea level canal and the minority preferred, as in 1879, the Godin de Lepinay's lake, dam and lock plan now in course of execution.

In the respective periods both majority and minority had thought of only one system of excavation, the excavation in the dry.

The International Congress was right in doing so in 1879 but the International Board was wrong in doing so in 1906, because in the meanwhile great progress had been made and a new factor entered into the play: The wet system.

The wet system of excavation, the excavation by floating dredges and the transportation of the spoils by barges to the dumps, is the system which made the Suez Canal possible.

Without it Mr. de Lesseps would have failed. He did not adopt it voluntarily, because his advisers, like the advisers of your government, actually were against it.

But one day the Khedive of Egypt, who was giving the compulsory labor to the Suez Canal Company, was forced by Lord Palmerston to suspend this practice. Lord Palmerston was a fierce opponent of the Suez Canal, he called it at the tribune of the British Parliament an enterprise of swindlers, and the suppression of the compulsory Egyptian labor was thought by him to be a death blow to the enterprise. It proved in fact what saved it.

Being without other resource the scientific advisors of Mr. de Lesseps could not oppose seriously Mr. Lavalley, an engineer of genius, then young and little known who said to Mr. de Lesseps: "Thank God, you have no more labor and at last you are going to be able to dig the canal!" "How?" said Mr. de Lesseps surprised? "By dredges for excavating "and barges for transporting."

Mr. de Lesseps accepted the proposition because his advisors were silenced by the absolute want of labor. Seven years later the canal was thrown open to the world.

What the dredge has done for the Suez Canal it has to do for the Panama Canal, and it will do it. In 1879 the dredge of Suez could not dig Panama because it had not been taught to bite rock. I made in 1885 the first step in that direction and it now does it admirably.

To think of making the sea level canal without giving it all its qualities, its entire independence from all artificial structure, such as locks and dams, is a great error.

The objections against the so-called sea level canal: its high cost, the undetermined period of its construction, the presence of a tide lock on the Pacific, and of a steel concrete dam on the Chagres before it enters the canal are all perfectly founded. They all apply to the narrow, tide locked, sea level canal they do not apply to the Straits of Panama.

They apply really to the method of construction and to the consequences it has on the type of the canal.

If you change the method of construction, if you attack by dredging, you will establish first a lock canal, but it will have no huge locks, no earth dam at Gatun. The steel concrete dam will be established at Gamboa less for the purpose of controlling the Chagres than for that of creating an enormous lake which will receive all the spoils, and give by its falls the energy for the works.

The dredges will work on the summit level and widen it to its full extension; then they will dig it and, while they will lower the bottom, water will also be lowered until the lateral levels are reached. The new summit level will be treated in the same way, thus all the successive levels will be eliminated and the sea level reached.

All these spoils will be brought by barges into the lake formed outside the canal, in the high valley of the Chagres, above the point where the river enters the canal line.

It will not only form the easiest and cheapest way of disposing of the spoils; for several miles the valley will be filled and a new and higher bed will be thus formed for the Chagres.

At the end of the digging the Gamboa dam will have ceased to exist as a dam. It will form the extremity of the upper new valley, but the water will not any any more press upon

it. The dam will have to play but the insignificant part of a retaining wall and nothing more.

It will have ceased to exist as an essential organ of the canal, earthquakes may destroy it. It will have no effect on the canal.

In this system the minimum will be left to the action of man and the maximum to the action of nature.

The electricity generated by the falls of the lake will put in action the rock breakers, the floating dredges, the scows. The water in the small barge locks, will raise the scows from the level of the summit to that of the lake, and the depths of the lake will absorb the material of the Straits. Thus the Chagres once harnessed will offer freely by its waters the way for the excavating and transporting instruments, by its falls the energy to animate everything, and by its upper valley the dump to receive the spoils.

To establish the first work lock canal four years are necessary, and to dig the Straits ten years more.

If you establish locks large enough to pass the largest men of war in existence, including the 26,000 tons warships just begun, 95% of the commercial vessels will be able to transit alongside the work during the excavation. The cost of dredging the Straits will be one hundred million dollars and the cost of the first phase, if constructed for temporary transit of ships, with locks 575 feet long and 110 feet wide would be also one hundred million dollars.

The total cost of the ideal solution, of the first class solution would be now $200,000,000 ; that is about what remains to be spent on the lake, dam and lock solution, on that solution which is not only unstable and condemned to a historical catastrophe, but which, even carried on, would be obsolete

before its inauguration owing to the constant increase of size of ships whether commercial or military.

It is the solution by which the progress of science allows us to-day to fulfill the order send by Charles V to Hernando Cortez in 1523 from Valladolid to go and search for the "Secret of the Isthmus." The "Secret of the Isthmus" is in the rational utilization of the Chagres.

I have tried to bring before you only facts and figures. I hope they have been eloquent enough to make you forget the insufficiencies of my English.

IMPORTANT COMPLEMENTARY POINTS ABOUT THE "LOCK CANAL WITH A DAM AT GATUN," THE "SEA LEVEL CANAL" AND THE "STRAITS OF PANAMA."

NOTE OF THE AUTHOR.

Though I proposed to speak of the following facts in the course of my address before the Commercial Club of Boston, I feared to ask too much of the patience of my hearers, and I was led to limit my remarks to the principal points and to give the lecture which has been inserted in the Congressional Record.

However, I feel myself at liberty to add them in this pamphlet as a complement to the address. They must be considered as a part of it, though they were not expressed by word of mouth.

Also, I have added as a third chapter what might be called the corroborative evidence against the "lock canal with a dam at Gatun." It is formed by the extracts from the testimonies of the engineer officers of the Canal before the Congressional Committee of Interstate and Foreign Commerce, in January, 1909, at Ancon—Canal Zone.

A Lock Canal may be Safely Established on the Isthmus, but Without a Dam at Gatun.

Does what I said mean that a lock canal is impossible of construction on the Isthmus?

Not at all!

The unsafe part of the actual lock plan is the dam at Gatun.

Why was it adopted? Will you ask! Here is the answer:

Any lock canal with a summit level must have a provision of water. This provision of water must be formed by damming the Chagres somewhere. There are four points where it can be proposed to dam the Chagres.

One at the lowest possible point of the valley, at Gatun on the canal line.

Another one nine miles higher up, at Bohio on the canal line also.

Another one just above the point where the Chagres enters the canal line, at Gamboa.

Another one 10 miles above the point where the Chagres enters the canal line, at Alhajuela.

The higher up you choose the point where the course of the Chagres is to be stopped by a dam and a lake formed behind the dam, the less water you collect in your reservoir because all the tributaries of the Chagres below the dam will flow to the sea and will not be stored in the lake.

This is the inconvenience of the location of the dams higher in the valley: the higher you go the less water you store.

The advantage on the other side is that the higher you go the higher also you meet the bed rock and the better are your foundations.

At Gatun the bed rock is at 265 feet below sea level.

At Bohio 9 miles higher up the valley it is 157 feet below sea level. At Gamboa 12 miles above Bohio it is at sea level, that is about 40 feet below the bed of the Chagres. At Alhajuela

10 miles above Gamboa the bed rock forms the bed itself of the river.

These inverse qualities of the various locations explain easily how in the different projects of a lock canal the site of the dam has been changed from one location to the other.

The engineers who do not care for the amount of traffic which a lock canal can serve and who look only for the easiness of construction of a perfect dam will choose the location of Alhajuela. There a masonry dam, the only kind of structure admissible for a high dam, is easy to erect.

It was the project of the new Panama Canal Company, but the easiness of the erection of a dam was in fact outweighed by the difficulty and danger of constructing a connection between the Alhajuela lake and the summit level which it has to feed.

The Gamboa location is perfect also from the point of view of safety. A masonry dam can be easily erected there with the assurance of complete stability because precise calculations of stability can be made for a masonry dam. On the other hand the Gamboa dam is in immediate contact with the summit level, and there is no difficulty nor danger in establishing the water communication between the lake and the summit level. All the conditions regarding stability are obtained there. But the amount of water received in the reservoir is only two-thirds of what would result from a dam at Bohio, while a dam at Bohio would also collect only two-thirds of the water which would be collected by a dam at Gatun. Therefore the limits of the capacity of traffic would be in round figures 26,000,000 tons with a dam at Gamboa, 40,000,000 tons with a dam at Bohio and 60,000,000 tons with a dam at Gatun.

It would be therefore impossible to construct a lock canal with a dam at Gamboa with any idea of perpetuity.

The Isthmian Canal Commission in 1901 was led to select the Bohio location for a dam because there the conditions were sufficiently good to ensure the establishment of a satisfacfory structure, though of a quality much inferior to that resulting

from the selection of Gamboa as the location for the dam, and at the same time the mass of traffic which could be served was sufficiently great (40,000,000 tons annually).

However the Bohio location could not admit the perfect type for a dam, the masonry dam, on account of the depth of bedrock. The Commission was forced to admit an inferior type of structure, the earth dam with a masonry core.

But when in 1905 the question of the type of the Canal came again to the front, the constant increase in the size of ships obliged the defenders of the perpetual lock type idea to recognize that with a dam at Bohio a lock canal could not be called perpetual on account of the increase of the consumption of water due to the necessity of increasing the dimensions of locks.

The intense desire of increasing to its utmost limit the storage of water was the only cause of the selection of the Gatun location for the dam. But there only an embankment of earth could be thought of as a dam and therefore the poorest kind of structure had to be resorted to. Instead of carefully observing the limitations traced by nature, instead of drawing a project inspired by these limitations, the contrary was made. It was nature which they tried to submit to the needs of a preconceived idea, the construction of a perpetual lock canal.

We can see now the results.

Nature cannot be forced to fulfill the ambitions of man outside of the limits which Science has to recognize and to fix.

When this is tried Nature reacts and man is as powerless against its reactions as the Lilliputians were when they tried to chain Gulliver.

The dam at Gatun will certainly succumb under the combined influences of the pressure of the lake and of the lubricating influence of the water on the soft, plastic, slippery clay upon which the huge embankment will be seated. This is the thing which is now demonstrated.

The Escape of the Water of the Lake through the Fissures of the Clayish Sandstone of the Hills at Gatun Another Great Danger. Will the Belt of Hills Enclosing the Lower Part of the Gatun Lake prove to be a Huge Sieve ?

But there is another fact which is of the greatest moment.

The huge locks will be erected on a kind of rock which is at the very limit between rock and earth. It is a mass of sand agglomerated by a green clay. Though strong enough, with a very narrow margin of safety, to stand the pressure of the walls of the locks, it is an unreliable ground. The insufficient resistance it offered to the shocks of the frequent light earthquakes of the isthmus have caused the interior compressions which resulted therefrom to open permanent fissurations. This is a very dangerous character, because the clay which unites the particles of sand is very liable to be carried away under a constant stream of water and slight fissures will be soon transformed into great ones.

This danger is sufficiently established to have caused Colonel Goethals to provide for a deep curtain of masonry in front and below the foundations of the locks in order to prevent this underground flow to pass below these foundations and to eat them up gradually.

How much will the curtains of masonry, in front of the locks and below the level of its foundations, keep the water from flowing in the fissurated ground underneath, is a matter of pure speculation. It would be necessary for absolute safety to bring the masonary curtain below the lowest fissures. Who knows their level?

But if this flow is sufficiently established to oblige the engineers to resort to such expedients near the locks, what may be thought of all the surrounding hills which will have to keep the water in place outside of the dam proper? Will they

fulfill their part faithfully and prevent the water from escaping through their fissurated mass? Will they not prove to be a huge sieve ?

This is not a danger which is actually demonstrated, but the provision of the masonry curtain in the locks demonstrates that the gravest suspicions may be raised against the lateral hills.

They seem to be as little able to keep the water in place as it is demonstrated that the subsoil below the dam is unable to keep the structure in place.

The Fissured Soft Rock with Soft Tufa Below an Exceedingly Dangerous Foundation for the Concrete Dam Which will be Erected in Gatun Hill for the Spillway.

A masonry dam is a perfectly safe structure and can be calculated with absolute precision provided it is resting on an extremely solid foundation. It is the most dangerous of structures if the rock below is not above any suspicion.

In the middle of the Gatun dam which will be made of earth, is a little hill where the outlet of the lake will take place through convenient regulating apparatus.

In order to erect the earth dam the river, during the depositing of the earth, will be deviated through Gatun Hill. The hill will be excavated down to 8 feet above sea level. After the earth dam is completed a masonry dam will be erected there and close the valley.

It will be resting on this soft argillaceous sandstone, where so many fissures have been discovered. The strength of such a sandstone is, compared to that of the red sandstone on which the masonry dam of Bouzey (France) was erected like lead compared to steel. The Bouzey dam was erected with the greatest precautions by the best engineers of France. Mr. Picquart, actually Minister of Marine and former commissioner general of the Exposition of 1900, was one of them.

It gave way because the red sandstone was not a sufficiently good foundation for a masonry dam. Its destruction entailed considerable loss of life.

The Habra dam also a masonry dam in Algeria met his fate in the same way on account of imperfect foundation.

Both structures had been considered for 20 or 30 years as perfect.

After such examples it seems a challenge to the laws of nature to build a masonry dam on the soft deliquescent argillaceous sandstone of Gatun Hill, when it is known that soft material like tufa underlies it, which a current of water will disintegrate immediately.

True it is to say that the engineers will endeavor to place a curtain of concrete in front of and below the foundation of the dam in order to cut the flow of water through the fissures which exist in the soft argillaceous sandstone. But it has been recognized that these fissures communicated between each other to a distance of 2,000 feet measured horizontally.

There is no reason to think that such extensive ramifications of fissures are limited to the surface; they must extend in the depth of the subsoil. The apron of concrete will simply oblige the water to go below the apron before flowing below the dam. That it will flow below the dam there is no doubt; that below the dam the argillaceous sandstone is underlied by a very loose tufa there is no doubt; that the argillaceous sandstone itself disintegrates in a current of water there is also no doubt. For anybody familiar with the history of masonry dams there is no doubt that the dam in Gatun Island will be undermined and ruined very quickly.

What Canal May be Called Perpetual? The Straits! Opinion of Sir John Wolfe Barry About the Method of Excavation Proposed: The Wet System.

This is another obvious and necessary consequence of the fact that the Gatun location has been chosen not account of sterling qualities which a dam imperatively requires, but on

account of the ambitious desire of giving to a certain type of canal; the lock canal type, a quality which nature prohibits to give him on the Isthmus—Perpetuity.

The only solution which may legitimately be called perpetual is the solution which is independent of the size of ships. It therefore must have no locks.

The only solution which may legitimately be called perpetual is the solution which is independent of any storage of water. It therefore must be at sea level.

The only solution which may legitimately be called perpetual is the solution which is independent of any artificial work because any artificial work such as the most perfect dam, the masonry dam, may be wrecked by an explosion of dynamite or by a very severe earthquake. It must therefore be free from any artificial dam.

The only solution which meets all the requirements of perpetuity and at the same time those of perfection is the wide, open, free junction between the oceans, 600 feet wide at average water level, 45 feet deep at the lowest tides, 500 feet wide at the bottom.

It is the project which I submitted, and which I characterized by the name of "Straits of Panama", to the consulting Board in 1905. It is this complete solution which Mr. Alfred Noble, the great engineer who has been the commanding figure in the camp of the Lock Canal party, declared recently to be the perfect and the ideal solution at the annual banquet of the alumni of the Stevens Institute. But he added that the cost and the time of its construction rendered it prohibitive.

I have answered in the "New York Herald" of Sunday, February 21, last, quoting the remarks of the greatest English expert living, Sir John Wolfe Barry. It is not unnecessary to reproduce the "Herald's" article.

Extract from the New York Herald of February 21, 1909.

M. BUNAU-VARILLA ANSWERS A "LOCK CANAL" ARGUMENT

SAYS ALFRED NOBLE'S SPEECH ADMITS SEA LEVEL PLAN IS ONLY SOLUTION OF PROBLEM—QUOTES SIR JOHN WOLFE BARRY'S APPROVAL OF HIS IDEA FOR "PANAMA STRAIT."

ASKS "IS 'GO AHEAD!' NO MORE AMERICAN?"

M. Philippe Bunau-Varilla, the eminent French engineer, whose views regarding the isthmian canal have aroused world-wide interest, made timely comment yesterday on some significant admissions made on the previous evening by Mr. Alfred Noble, a leading American engineer, concerning the Panama Canal.

At the annual dinner of the Stevens Institute of Technology, held in the Hotel Astor, Mr. Noble, who is chief engineer of the Pennsylvania Railroad and was successively a member of the Nicaragua Canal Commission, then of the Isthmian Canal Commission which had to decide between Nicaragua and Panama, and finally a minority member of the International Consulting Board, the majority of which voted for a sea level canal, spoke of M. Bunau-Varilla's plan in the following terms:—

"I realize fully that in this vicinity a preference for a sea level canal in Panama is natural. Such a broad channel at sea level as the one advocated by the eloquent and ingenious M. Bunau-Varilla and by him appropriately designed as the 'Strait of Panama,' would afford a quicker and safer navigation than any possible lock or summit level canal. But on account of its enormous cost and the prolonged period required for its completion the 'Strait of Panama' must long remain a work of the imagination rather than of practical realization."

"DIVIDES FACES OF SUBJECT."

M. Bunau-Varilla was asked yesterday by a reporter for the Herald if he had anything to say on Mr. Noble's statement. He answered:—

"Mr. Noble is one of the greatest engineers living. Whatever he says must be listened to with respectful attention. In a few words he has divided admirably the two faces of the subject.

"The 'Straits of Panama,' according to the opinion of this commanding figure among the sponsors of the lock plan, is the only complete and perfect solution of the Panama problem, the only one which will insure safety and rapidity of navigation more than any other plan.

"This statement is of capital importance, because it is a statement of general principles. It eliminates the idle arguments of those defenders of the lock plan who tried to persuade the world that it possessed advantages over the free, natural, open highway between the oceans. It was as idle to say that as for a surgeon to maintain that a wooden leg is preferable to a natural one. But, however many persons were brought to believe it, Mr. Noble though having signed and still defending the actual lock plan, proclaims it an inferior solution.

"Mr. Noble's statement might be written as follows:—'Though the 'Straits of Panama' constitute the most perfect solution, we had to be satisfied with another of inferior order affording less security, because the best solution was above our resources and would take too much time.'

"IS 'GO AHEAD!' NO MORE AMERICAN?"

"America has been distinguished as the land of unlimited possibilities. Its discovery was due to one of those splendid efforts by which the human mind has successively broken through the limits within which timidity and routine incarcerated human action. I have been brought up in the admiration of this energetic race, which, with the hand on the plough and the revolver at the belt, conquered a continent to humanity, which connected the two great oceans of the planet with a continuous line of iron and the two great continents of the planet with a continuous line of copper. How can its greatest engineers to-day speak as the bishops of Salamanca spoke to Columbus. 'What you propose to do is beyond the limits of possibility'? Is 'Go ahead!' no more American?

"Even if the complete solution of the Panama problem was really beyond the reasonable limits of time and expense, it should be kept conspicuously in view. It should be shown as the final goal, and the genius of the human race should be invited to forge the tools with which it can be reached. This is how the transcontinental road was built; this is how the transoceanic cable was laid; this is how the Suez Canal was dug.

"But we have not to look forward for the tools which can open the 'Straits of Panama.' The 'Straits of Panama' would be indeed beyond the limits of actual human possibility if we tried to dig them by means of steam shovels and transport the spoils by trains to the dumps. Even the so-called sea level canal, with its width only one-third that of the 'Straits' and with its reduced depth, with its tide locks established on the Pacific side in order to prevent the tidal currents from entering a narrow canal and disturbing navigation, would require from thirteen to twenty years to dig by the method of dry excavation. The 'Straits,' therefore, would take by the same method forty to sixty years.

"But if you change the method, if you dig and transport by instruments floated on water, what is an impossibility in the dry system becomes not only practicable but easy in the wet. The realization of the first class solution—the 'Straits of Panama'—will not only cost much less than the second class solution—the tide locked sea level canal—but it will also cost less than the third class solution—the lock and lake solution, with its terrible sword of Damocles hanging over it—the Gatun dam.

"To this I know Mr. Noble will answer, 'Your proposition would be all right if it were not for the rock which will be found in the excavation and which a dredge cannot bite.' This might have been said twenty-six years ago, but it can no longer be said now. Enormous advances have been made in this branch of engineering. Mr. Noble acknowledged it when, as a member of the Isthmian Canal Commission, he signed in 1901 a list of standard prices where the extraction of rock under water was set at $4.75 a cubic yard, and when five years later he signed as a member of the International Board of Consulting Engineers another list of standard prices, where

the same work was fixed at $2.50 and where the dredging of loose material, including transportation and dumping, was fixed at fifteen cents a cubic yard.

"A Concession to Progress."

"This was a great concession to progress, but was it a sufficient one? No. The art of extracting rock under water consists now in breaking the rock, in transforming it into loose material. The two prices above named show that this operation of loosening the rock and making it as dredgable as sand was calculated by the consulting board at $2.35 a cubic yard. What does it cost in reality?

"This has been shown by reports brought before an association of engineers which is second to none—the Institution of Civil Engineers in London—at the conference of June, 1907. The official reports from the works at the Suez Canal and at the harbor of Blythe have shown that the cost in these two instances was about twenty cents a cubic yard. The verbal statements of the chief engineer of the Manchester Ship Canal also showed at the conference that the cost had been there only twelve and a half cents a cubic yard. Therefore the standard cost admitted in 1906 by the Consulting Board for loosening the rock was proved in 1907 to have been respectively ten times and eighteen times greater than reality demonstrated.

"Need Not Be Defended."

"This is the real weight of the arguments under which, as General Edwards said recently, was crushed the project of the 'Straits of Panama' by the International Consulting Board in 1906. It needs for its defense neither eloquence nor ingenuity, because it is the expression of the dream of the centuries and because the progress of industry and of science has already forged the tools which to-day make the 'Straits of Panama' the most practical and the most economical of all the plans from the point of view of construction.

"It need not be defended. It defends itself. But a man who exposes his own ideas may always bo accused of looking at them through rose colored glasses. Hear the voice of a perfectly independent judge, of a man who is certainly the greatest living English engineer, the voice of Sir John Wolfe Barry, who made the latest bridge in London—the Tower Bridge. He presided over a meeting of the Royal Society of Arts in London at which, in January 1907, I developed the conception of the 'Straits of Panama' and of the scientific methods by which they can be constructed. I extract from the journal of the society a part of the commentary he made after my lecture:—

"'*In principle one could not help being captivated by the idea that the work could be constructed and brought to a proper issue by the use of water as the carrying power for the machinery to do the excavation, and as the carrying power for the transport of the dredged material to its destination. One could not help being struck also with the great ingenuity by which a large receptive place could be made where the dredged material could be deposited at a level which was sufficiently convenient for the barges to reach.*'

"The broad principle commended itself to an engineer at once, that if it was possible to use the flotation power of water to bring the excavators to the

place where the excavation had to be made, and if it was also possible to take the barges from the dredger to the place for which they were destined, it would solve some of the greatest difficulties in dealing with such a work in such a country. As the author said, instead of treating the great rainfall as an enemy he converted it into a friend and an ally, and if this plan could be carried out it seemed to him a most valuable suggestion.

"Very Well Knew the Great Cost."

"'His own experience went to corroborate these views entirely, because he very well knew the cost of excavating in water-logged strata when the excavation was made in the dry, where the rain caused innumerable slips of earthwork and occasioned the greatest difficulty in maintaining the roads. If these difficulties could be avoided an enormous amount of trouble would be done away with and *a price reached which would be far and away less than anything which could be contemplated for excavation in the dry.* He supposed one might almost say that the Suez Canal would have been impossible of construction if it had not been for the great improvement in the dredging plant which took place at that time, although in that instance the distances to which the earth had to be transported were comparatively short.

"'Since that time the development of dredging plants had gone on by leaps and bounds and engineers were now able to use dredgers supported by water at the spot where the work had to be done—dredgers of a power and celerity of excavation never dreamed of in former years.'

"Speaking of the Suez Canal, as one of the former members of the International Technical Consultation Commission of the canal, Sir John Wolfe Barry said, further:—"'*It was at one time considered that the excavation of rock between the Bitter Lakes and Suez, for the purpose of deepening the canal to suit the modern requirements of ships, presented such a serious obstacle that the work was suspended for many years, although everybody knew it would have to be done. But that difficulty disappeared. The work was done without explosives, the traffic of the canal was not interrupted, and the price at which the excavation of the rock under water was done was given by Mr. Kellennec at one shilling a yard.*

"'Mr. Hunter also stated that he excavated the rock in the Manchester Canal under water by the same Lobnitz process at nine pence a cubic yard, and these prices engineers must take as facts. *Taking these prices as true—and they must be so considered on the evidence of such eminent engineers—it did seem a very startling proposition that engineers should be contemplating at the present time such a very large price for the Panama Canal as ten shillings a cubic yard (2.50) for rock excavation.*

Danger of Earthquakes.

"'He (Sir John), therefore, thought every one would welcome the idea which the author had enunciated, that they need not be content with what one might call a canal, but might look forward to what had been better described as the 'Straits of Panama.'

"'Another thing which struck him was that the recent sad experiences at Jamaica and in Valparaiso and in California seemed to indicate that a great work of international importance in such a locality as Central America and the Isthmus of Panama ought, if possible, to be so designed that what were called 'works of art' should be altogether avoided. A lock system canal in a volcanic neighborhood subject to earthquakes could not be contemplated with complacency, and when the enormous amount of money which was to be spent on the work was taken into consideration, it seemed to him as an outsider—because he was only an outsider in that particular matter—that anything in the nature of large masonry dams and locks closed with gates, which would be absolutely wrecked by comparatively light shocks of earthquake, should be avoided in such a magnificent enterprise.'

"Thus spoke the man who may be called the highest exponent of hydraulic engineering in England," added Mr. Bunau-Varilla. "It counterbalances the opinion expressed in a certain technical organ, which termed 'fantastic' the new method of digging the 'Straits of Panama.' I am only sorry it has found access to and was reproduced in the Canal Record, which, as you know, is published under the authority of the Isthmian Canal Commission.

The Method of Discussion Adopted by the Opponents to the "Straits of Panama."

The absolute perfection of the "Straits of Panama" is obvious for any man. It covers so clearly all the requirements which must be fulfilled by an artificial waterway across the Central American Isthmus that its opponents, the sponsors of the perpetual lock canal with an earth dam at Gatun, the sponsors of the third class solution, as well as the sponsors of the narrow tide locked "sea level canal" with a steel concrete dam at Gamboa, the sponsors of the second class solution, cannot find an argument against it.

Their strategy simply consists in acknowledging its perfection but in dismissing it without any further discussion by calling it chimerical. They add for sustaining this contention that this project was examined and rejected by the majority and by the minority of the Consulting Board in 1906.

This being done by tacit and mutual consent of the sponsors of the lock plan and those of the sea level plan the questions asked from both about the "Straits of Punama" are answered as if such solution had never existed and a wilful confusion is thus made between this solution and the one called "sea level canal." The objections made against the "sea level" plan by the defenders of the "lock plan" are thus injected into the public mind as applying to the "Straits of Panama" plan. It is however obvious that the reproach of having tide locks, the reproach of having a high masonry dam, the reproach of consisting of a narrow and deep cut which may be closed by a slide do not in any degree apply to the "Straits of Panama" plan which is free from any locks, from any dam, and which provides for very wide waterway.

Another unfair method of discussion is that of comparing the dam at Gatun with its head of 85 feet with the dam at Gamboa with its head of 170 feet in the sea level plan, and to say that the second one will be more dangerous than the first

on account of its greater head of water. It is a misleading argument which cannot be expressed by any engineer worthy of this title.

The danger for a dam is not the head of water it has to stand, it is the nature of the foundation upon which it is seated.

A dam having the level of the water 300 feet above its foundations like the Croton dam is a perfectly safe structure, if its masonry rests upon solid rock and if the masonry is made with the cement of required quality.

A dam of earth even with a head three times smaller is a highly perilous structure if it is resting, like that of Gatun, on a semi fluid clay without supporting power.

CORROBORATIVE EVIDENCE BEARING ON THE FACTS WHICH HAVE BEEN SIGNALLED IN THE BOSTON LECTURE AS ENTAILING THE GRAVEST DANGERS FOR THE SAFETY OF THE PANAMA CANAL.

This corroborative evidence may be obtained from the hearings before the Committee on Interstate and Foreign Commerce of the House of Representatives at the Hotel Tivoli, Ancon, Canal Zone, January 6 and 7, 1909.

The facts brought out in the hearings are precisely those which always since the actual lake, dam and lock plan was adopted in 1906 convinced me of its extreme instability, of the radical defects which should lead to abandon it at any cost and as early as possible.

The distinguished army engineers who testified before the Committee report these facts with their usual scientific straightforwardness.

It will certainly astonish the readers to see that in spite of these ominous facts they still adhere to the opinion that the actual plan can be carried out.

There is not the slightest doubt that if the facts actually demonstrated had been brought to light in 1906, there would not have been a group of engineers to recommend an interoceanic canal, the very existence of which had to depend—1st upon such suspicious and wholly unexperimented theories of equilibrium for the earth dam at Gatun; 2nd upon such deficient foundations for the locks and the masonry dam at Gatun island as that formed by argillaceous sandstone rest-

ing on this mixture of sand and volcanic ashes called tufa, when it is known that this ground is fissurated and that water flows through it; 3rd upon the unwarranted and suspicious assumption that the hills encircling the lake will be watertight, when it is demonstrated they are fissured by crevices and cannot but loose water in unknown quantities, when the existence of the lake must give to the water in these fissures a head of two atmospheres and a half, and force it to find new outlets very likely in the vicinity of the dam.

In all conceptions of the engineering mind reality brings forward supplementary difficulties which had not been seen at the outset. It is a natural and wholly justified tendency of those in charge of the execution not to effect a retreat in face of the first difficulty but to try to overcome it. But there is a limit to that sort of courage. And the limit exists when the risk for the work undertaken becomes so great as to be wholly inacceptable as in the present case.

But whose duty is it to proclaim that the limit has been passed? Whose duty is it to order the abandonment of the plan?

It is not wise to ask that from the authors of the project. Their mind is not free, it works under the load of a preconceived idea which destroys the elasticity of their judgment and debilitates their faculty of observation.

It is not wise either to ask that from the engineer officers to whom has been entrusted the honor of winning that great battle against nature. For them to say that the difficulties encountered are above the resources of practical engineering; for them to say that the actual project must be abandoned because there is no certainty even remote of the stability of its main structures except by a veritable miracle, it is like avowing a defeat and sounding the retreat. What the reason and wisdom of the engineer advises the brave heart of the officer refuses to express. This conflict between the two noble sides of the conscience of the

engineer officer is more manifest than anywhere in Major Sibert's testimony of which abstracts are given hereafter. The facts he shows condemn the plan as a secure one, but when asked if he has lost confidence in the actual canal, he says: "I think it can be built." It recalls, though inversely, that struggle in Galileo's mind when, after withdrawing on his knees his own theories about the movement of the Earth before the Tribunal of Inquisition, he exclaims, when rising: "Nevertheless it moves."

The duty of sounding the necessary retreat is incumbent upon the supreme authority, which has before the world the responsibility of creating a stable, perfect junction between the oceans.

This is why it would have been so necessary for the American administration to send recently to the Isthmus a body of unprejudiced, free minded engineers to confront facts with opinions and report the conclusion.

Unfortunately this board of engineers which was originally to consist of six persons, but which was brought to seven at the last moment, was not composed either of men entirely free from any preconceived ideas or even of men in equal number and known as supporting adverse theories. Three members of the Board were known as intimately associated with the actual plan, two MM. Stearns and Randolph for having proposed and signed it in 1906, another Mr. Freeman for having approved it unqualifiedly as a member of the Board, which went to the Isthmus with Mr. Taft in 1907, and which was formed of himself and of two of the signers of the plan, MM. Noble and Stearns. The opinion of the Board of 1909, like that of the board of 1907, are therefore not independent expressions of opinion. The spirit of the minority of the consulting Board of 1906 must be considered as having been the predominating influence in 1909. The report of 1909 like that of 1907 are nothing but the two successive echoes of the report of 1906.

Let us now come to the facts as developed by the testimonies of the Isthmian Canal officers before the Congressional Committee.

The Yellow Tufa.

On the question on the yellow tufa which is found below the argillaceous sandstone in the foundations of the locks and in the foundations of the masonry dam on Gatun Island Major Harding answered as follows:

Mr. Stevens: What is the yellow material of which you informed us?

Major Harding: The yellow material seems to have been formed in part by a deposit of volcanic tufa, *a mixture of sand and volcanic ash*. It is a yellow, light material which is of volcanic origin. That material changes gradually from soft sandstone into argillaceous sandstone with tufa mixed. The change is so gradual that it is impossible to draw a line and say above this line is soft sandstone and below this line is argillaceous with tufa mixed.

Mr. Stevens: What do you propose to do with this yellow, soft sandstone in the lock foundation?

Major Harding: I propose to test all parts that are, in my judgment, at all doubtful to at least twice the load that is to come upon them. If the material thus tested settles appreciably I would propose that that material should undoubtedly be removed and the removal continued until material sufficiently strong to stand the test without any question is reached. The extent of this material, both vertical and horizontal, is a matter of judgment pure and simple, and the question of whether it should be removed locally, the soft parts being taken out, or a general removal of everything, including the good and the bad, down to a certain level, is also a question of judgment.

Mr. Stevens: When you remove the tufa and doubtful material, what will you put in its place?

Major Harding: Concrete.

Mr. Stevens: Just as a dentist plugs a tooth?

Major Harding: Yes, sir.

Mr. Stevens: So you propose to go to that depth and find a foundation which you are sure will prove safe for the load that will be placed upon it?

Major Harding: I do.

Why the Height of Gatun Dam Was Reduced.

On the question of the reduction of the height of the Gatun dam Major Harding explains why it was proposed. Far from stating, as it was officially announced that the Board of

Engineers which went with President-elect Taft did, that the Gatun dam was unnecessarily high and strong, Major Harding says that the reduction of height is proposed to increase the stability of the dam in reducing the pressure on the soft clay upon which it will be seated.

Mr. Esch: I understand the original plan was to have the dam 135 feet high?

Major Harding: Yes, sir.

Mr. Esch: It is now contemplated to build it only 105 feet high?

Major Harding: There was a proposition to that effect, to which I subscribed—to reduce the height to 105 feet instead of 135 feet.

Mr. Esch: Would that diminution in height lessen the security of the structure?

Major Harding: *I think it may possibly increase the stability of the structure.*

Mr. Esch: Explain that, please.

Major Harding: The weight of the material that is going to form the dam has been measured, and it gives a pressure at the bottom of a ton to the square foot for every 20 feet in height; so, *if we lower the level of the crest of the dam 20 feet we take off a ton to the square foot of the base of the dam underlying the part that is taken off.* In other words, the pressure on the foundation of the dam will be a ton less per square foot than it is at the present time. The crest, 105 feet high, is 20 feet higher than the maximum level of the lake; it is 15 feet higher than the lock walls or lock gates: and it is higher than some of the natural hills that form the limits of the lake. The height of 20 feet above the lake is certainly ample to take care of any wave action that might occur. The horizontal dimensions of the dam, if the height is reduced 20 feet, would remain the same as they were before. The final 20 feet in the dam would cost more than the rest of it per unit, and I can conceive no useful effect of that excessive height, unless it be to provide a margin of safety to take care of any settlement that it may be anticipated will hereafter occur.

What Will Be Below the Foundation of the Masonry Dam of the Spillway.

On the question of primary importance of a perfect foundation for a masonry dam Major Sibert explains that the masonry dam at the spillway will be seated on argillaceous sandstone underlied by tufa described by Major Harding as a mixture of sand and volcanic ashes. He further states that the ground is fissurated.

These are conditions infinitely worse than those which

caused the catastrophe of the dam at Bouzey (France) and that of the Habra dam in Algeria.

Mr. STEVENS: Did you find a good foundation for the walls of the spillway?

Major SIBERT: Yes, sir.

Mr. STEVENS: What is the formation?

Major SIBERT: Argillaceous sandstone.

Mr. STEVENS: And you did not find softer stone and tufa?

Major SIBERT: *The same material is there but lower down.* We did not have to go so deep for the foundation of these walls as in the locks.

Mr. STEVENS: What is the height of the miter sill of the spillway above sea level?

Major SIBERT: The miter sill applies to the locks only. The height of the foundation would be the point you are after. The spillway itself would not have been excavated to anything near the depth it is now had it not been necessary to use it as a diversion channel for the Chagres while we were building the dam between the hills; but the depth of that excavation was fixed by the probable height the Chagres River would attain during floods, and we dug it down. It is now 8 feet above sea level. We figure that when the Chagres goes through there, it will not attain such a height as to interfere with our work, and we will ultimately build a concrete dam across founded on this 8-foot elevation. The top of the concrete will be about 16 feet below the lake level, and on the top of the concrete dam we purpose placing regulating works which will control the water in the lake.

Mr. STEVENS: Then you see no element of unsafety in the construction of the spillway?

Major SIBERT: No, sir. We propose to blanket all that hill; to excavate on the south face of the hill until we have passed through the strata that carry water the most, and to cover that face with concrete and let that join on to the sheet piling, and then we propose to cover with concrete all exposed rock surface to which the lake will have access, so that no water can get into this rock; and we purpose to blanket the south face of Spillway Hill with impermeable material, pumping it there as in the dam, thus practically shutting off the lake from this hill. It is a small hill isolated by these gorges.

THE POSITION OF MAJOR SIBERT IN THE CANAL COMMISSION.

The extremely important facts stated by Major Sibert make it necessary to know that he is the responsible head of the locks and dam construction at Gatun.

Mr. STEVENS: What is your position, Major, in the Canal Commission and its work.

Major SIBERT: I am a member of the Isthmian Canal Commission and at present in charge of the work in the Atlantic division. This work includes the construction of the Gatun locks and dams, the excavation of the sea-level

portion of the canal in that end, and the construction of any works necessary in Colon Harbor.

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Mr. STEVENS: When did you come to the Commission?

Major SIBERT: I left the United States March 10, 1907.

Mr. STEVENS: Since that time you have had charge of lock and dam construction at Gatun?

Major SIBERT: Yes; I had charge of all lock and dam construction on the canal until last July, when the work was divided according to territory and not according to class of work.

WHAT IS THE CONTROLLING ELEMENT OF THE SAFETY OF THE GATUN DAM? WHAT WILL OCCUR IF IT FAILS?

It will be seen by Major Sibert's testimony that the controlling element of the stability of the Gatun dam is in his opinion the one I denounced in the New York Herald of December 12 as unsafe, the soft blue clay. The danger of destruction he foresees is only the lowering of the crest of the dam below the water level of the lake. It does seem however certain that also in case of the settling of a part of the dam fissures will be opened between the part in motion and the one which will remain in place and outlets through the dam will be offered to the waters of the lake which will result in an immediate destruction.

The important thing nevertheless is to register the facts brought out in the following quotations of the distinguished officer.

Mr. HUBBARD: You are building an earth dam there, I understand. So far as the dam is concerned, you do not expect, and perhaps do not want, a rock foundation except as to the spillway?

Major SIBERT: I would like to have a rock foundation wherever I can get it.

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Mr. RICHARDSON: You say you would rather have a rock foundation?

Major SIBERT: Yes, sir.

Mr. RICHARDSON: Because that more certainly can balance—can bear the great weight, can carry any load that comes on it. It is your opinion that it will resist all pressure and that it is absolutely safe, which is based on the fact that you believe that you have got at Gatun dam a safe foundation?

Major SIBERT: We have not a rock foundation there under the dam, but under the locks we have.

Mr. RICHARDSON: Is it not a fact that on the safety of the foundation of he dam the whole canal depends?

Major SIBERT: Yes, sir.

Mr. HUBBARD: Judge, allow me to ask if you are distinguishing between the lock or dam, and if you are speaking of the Gatun dam?

Mr. RICHARDSON: Yes; I am speaking of the dam.

Major SIBERT: *The success of the dam depends upon having a good foundation. If you can not build the Gatun dam, you can not carry out the present project.*

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Mr. RICHARDSON: And it is not true that all the precautions you can take in putting in material to resist the pressure of the water, that if the foundation is not good, all that counts for nothing?

Major SIBERT: *If the foundation will not bear the load, we can not build and maintain the dam.*

Mr. KNOWLAND: But in your opinion, Major, you think it can?

Major SIBERT: I think the dam can be built.

Mr. KNOWLAND: And will hold?

Major SIBERT: I think so.

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Mr. STEVENS: What doubt is there about the dam itself? Where is its weakest point?

Major SIBERT: *The only weak point in the dam is its foundation.*

Mr. STEVENS: Over the whole length of it?

Major SIBERT; No; not over all of it. *Over that part of it where this blue clay, this slippery clay, comes closest to the surface.*

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Mr. STEVENS: Then, we are getting down to the crux of the danger of the whole proposition, viz, that some of the underlying material in the gorge, the treacherous portion of it, may slip through for various reasons. If that should happen, what would be the result as to the portion of the dam immediately over that slip?

Major SIBERT: *If the material under the dam were displaced—enough of it—to let the dam down so that water could run over the top of it, it would all go out.*

Mr. STEVENS: *What precautions are you adopting to meet that possible contingency?*

Major SIBERT: *You can not adopt any.*

THE NEW METHOD RESORTED TO IN ORDER TO PREVENT THE ESCAPE OF THE SOFT CLAY FROM UNDER THE DAM.

Major Sibert explains how it is hoped to prevent the soft material from escaping from under the dam by loading laterally the natural ground on both sides of the dam, so as to prevent it from rising by the upward pressure of the clay underneath when pressed out by the dam.

This is a method which has no antecedent and at which no engineer should look complacently.

The soft clay must be considered as a semi-fluid matter. The transmission of the pressure it sustains at a given point is entirely dependent upon its stage of fluidity.

Nobody knows nor can calculate what will be the fluidity of the soft clay or even of the stiffer variety met under the dam location when the water will be allowed to rise behind the dam.

The conditions of equilibrium obtained during the construction of the huge earth embankment will not in the least resemble those which will exist when the lake will be formed.

The incessant movements of the clay below, which are already apparent with the relatively small load of the rock toes on the ground, will continue and cannot be but expected when the dam is in course of erection, and when the pressure exerted on the ground will gradually rise to perhaps eight times more than the rock toes determine.

The movements which Major Sibert expects during the erection of the Gatun dam as an earth embankment will have largely disintegrated the clay, will have allowed it to absorb more water and increased its fluidity.

Admitting a satisfactory equilibrium be obtained for the earth embankment, it will not in the least give the slightest indication as to what will be the equilibrium with the water behind.

The pressure of two and a half atmospheres which will be that of the lake water on the base of the dam, will inject into the clay a new mass of liquid element which will increase its fluidity. The conditions of the former equilibrium which are determined by the fluidity of the clay will be then entirely and radically altered for the worse.

Major SIBERT: As I stated before, I think we can build a dam there on all the foundation.

Mr. STEVENS: Let us analyze the matter, Outside of this soft part, what reason is there to doubt its safety? What factor is there which would cause it to be unsafe out of the soft part?

Major SIBERT: None, except the ability of this material to stand the load, and it is so far down as to be out of the question.

Mr. STEVENS: Then you would not question that part of it?

Major SIBERT: No, sir.

Mr. STEVENS: As to the treacherous part, what are you doing to overcome the difficulty?

Major SIBERT: *We are so balancing, so arranging, the material north and south of the dam as to prevent any displacement of this material that we are now speaking of.*

Mr. STEVENS: Is that a matter of *calculation or experience?*

Major SIBERT: Largely a matter of *experience.* We get on the Isthmus a great deal of experience in that line in connection with the dumps, and especially with the fills of the Panama Railroad, and it is in these two lines that our experience here lies.

Mr. STEVENS: Now, if your experience shows that a mistake has been made, and the balance can not be created at the time you expect, what happens?

Major SIBERT: During construction, if it happens, we continue to put more material in, and add more load above and below the dam, and continue building until we have a structure that will stand.

Mr. STEVENS: You just continue?

Major SIBERT: Just continue; that will be done before the lake is formed.

Mr. STEVENS: What tests are you making to continue your experiments in the line of balancing as to this treacherous or deficient portion?

Major SIBERT: We will make no tests, except actual test of building. That is the only way we can load it, as it goes up. If there are slips, and there may be slips, we will meet them as we go along.

Mr. STEVENS: Then, you expect more slips?

Major SIBERT: Yes; I expect more slips.

Mr. STEVENS: Constantly.

Major SIBERT: I expect slips.

Mr. STEVENS: Do you consider it as a part of the dangers to that treacherous portion that there may be underground seepage?

Major SIBERT: I do not; that is, no deep seepages. *I am rather of the opinion that that part which is soft is made soft by water seeping from the hill.*

Mr. STEVENS: And that would be the utmost damage that would be caused by seepage?

Major SIBERT: I can imagine no damage to this dam caused in any other way than by slips. I believe the dam to be water-tight, and if water-tight no current can get through it. Settlement and erosion are the only two things, barring earthquakes, and if it is impermeable, as I think it is, bottom and top, I believe we can get no current of water in it that will destroy its foundations.

Mr. STEVENS: So that the real danger is in the unequal distribution of loads over the treacherous portion, causing slips?

Major SIBERT: That is the only thing that I know of, and that ought to be met in the building.

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Major SIBERT: If it ever let any water through at all, it would go; that

is, at the top. *If it settled so that a little stream as big as your finger started over the top of the dam, it would go?*

Mr. STEVENS: So you have to have a dam large enough to meet any question of subsidence for some years to come?

Major SIBERT: It would be better to so build it as to absolutely remove all risks of subsidence. *If it starts after the dam is built, it is difficult to say how far it will go.* It is best to meet it in the beginning.

Mr. STEVENS: In what way are you meeting it?

Major SIBERT: We are meeting it by so placing the loads above and below the dam as will prevent subsidence, and will prevent any movement of material from under the dam.

Mr. RICHARDSON: When you speak of so balancing the material, what do you mean? You have a dam so wide and so high, constructed by the pumping of certain material. What do you mean by so balancing this material?

Major SIBERT: The heaviest load on the foundation will be under the highest part of the dam. If the material on which the dam rests is not confined it must buckle up somewhere, if overloaded. If it can not move, the dam can not settle. We are adopting the plan of extending the fills above and below the dam, so as to weight down the ground to such an extent as to confine the material under the dam in case it should be overloaded. If the underlying material can not move the dam can not settle.

Mr. RICHARDSON: This balancing method consists of making the bottom of the dam exceedingly wide?

Major SIBERT: Yes.

Mr. RICHARDSON; Then the balancing you speak of takes place when you make the plans for the great width of the dam, and not when you dump the material?

Major SIBERT: The dumping of the material is simply carrying out the plan. The plan is to carry the toes so far as we have material to carry them, and so extend them as to balance the pressure of the dam.

THE REASON OF THE SLIDE OF THE ROCK TOE WAS NOT THE SILT IN THE OLD FRENCH CANAL, IT WAS THE LACK OF SUPPORTING POWER OF THE BLUE CLAY UNDERNEATH.

Major Sibert gives a very clear explanation of the reason of the slip of the rock toe at the crossing of the old French canal. He, at the same time, says that there were many other slips which show how the subground is working already under the relatively light pressure of the rock toes.

Major SIBERT: We pumped out of the Chagres and canal and will pump out of the west diversion all silt deposited by the streams, so as to get down to the original geological formation, and allow the superstructure of the dam to come in direct contact with this material.

Mr. STEVENS: Then this slide took place in the French canal?

Major SIBERT: *We have had several slides.*

Mr. STEVENS: The large one—now, would it not have been more reasonable to expect this slide in the channel of the old Chagres River?

Major SIBERT: Not if you examine the profile. There is underlying this dam a stratum of dark-blue clay of various degrees of consistency. In some places it is quite soft, and in some places harder. Overlying that is a stratum of a yellow mixture of sand and clay of varying thickness. In some places this blue clay is at sea level. In some places it is in the neighborhood of 70 feet below sea level. The thickness of the overlying sand and clay varies accordingly. That is about the general condition. The material upon which the slip occurred in the French canal is much nearer the surface than such material is under the Chagres River. There were some little subsidences is crossing the Chagres, but not such as had occurred in crossing the French canal.

Mr. STEVENS: *You have not had any slip in the north toe?*

Major SIBERT: *Yes; a good many small ones.*

Mr. STEVENS: And you anticipate more as the work increases?

Major SIBERT: That would be the natural assumption. There is quite a soft place at the end, and there *have been considerable gradual subsidences and the tracks have to be raised to keep up to level.*

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THE FISSURATIONS OF THE ROCK IN THE NEIGHBOURHOOD OF GATUN.

Major Sibert in speaking of the aprons or curtains of masonry to be constructed below and in front of the foundations of the Gatun locks in order to prevent the water from flowing underneath the locks and undermining them says:

Major SIBERT: Yes, sir. This country is fissured, I do not know to what depth, and you do not know that that curtain wall is down below all the fissures and is cutting out all access to the fissures.

THE EFFECT THE UNDERGROUND FLOW OF WATER MAY HAVE ON THE RESISTANCE OF THE FOUNDATION OF THE LOCKS AND OF THAT OF THE MASONRY DAM IN GATUN ISLAND.

Major Sibert recommends a very solid floor for the locks because he fears that the water if allowed to pass through fissures of the floor will disintegrate the foundation and he gives a striking example in point.

But it must be remarked that the same effect will take place if the water passing through the fissures open for themselves a new outlet near the dam. This seems to be nearly certain.

The actual outlets, believed to be in the sea, would evidently be changed for very near ones under a head of 85 feet of water such as will take place when the lake is formed. This seems highly probable because the strata of ground which may counterbalance a head of 8 to 10 feet will not do so with a head of 85 feet. In such case the velocity in the crevices will be enormously increased and the disintegrating influence on the ground correspondingly increased.

The CHAIRMAN: You say a secure and efficient lock may be had?

Major SIBERT: If you can prevent the breaking up of the lock floor.

The CHAIRMAN: Why do you make this condition, when you say as an engineer that you can have a safe floor to your lock?

Major SIBERT: In the investigations to determine the character of the material under this lock we dug a test pit near the lock site, going down through the same material that is encountered in the foundations of this lock. We came down to this soft sandstone of a blue variety, and we placed on that a test load of 500 pounds to the square inch, and that load finally—the whole thing—turned over, and *an investigation of it afterwards showed that the particles of sand in that stone were carried out by erosion caused by ground water coming up and escaping at the edges.* If we give any outlet to this water, this same thing is liable to occur by the water passing through these crevices in addition to the ground water which did take this sandstone away. If the water has no outlet, it must go on, as it always has done for centuries, through the small crevices in this rock to the sea, and the further it goes the less power it has to do damage, as it loses head by friction, and it can scour nothing if it can go on its old road to the sea.

It is not out of place to remark that the pressure of the masonry on the ground will not be very far from the experimental pressure of 500 pounds to the square inch which ended as Major Sibert just described by the tipping over of the load.

We have the necessary information from Major Harding's testimony.

Mr. STEVENS: What is the action of blue sandstone under water, air, and pressure, such as in this lock foundation?

Major HARDING: An actual test load of 500 pounds per square inch was made on the blue soft sandstone, which during the period of the test was exposed to the atmosphere, and from which the water was excluded. Under the test load of 500 pounds per square inch there was no settlement of the material.

Mr. STEVENS: What would be the load of the lock wall?

Major HARDING: The maximum pressure occurring per square inch under the most adverse conditions of loading, which conditions would be of a temporary character, is 250 pounds per square inch.

THE FISSURES IN THE GROUND COMMUNICATE WITH EACH OTHER. EXPERIMENTS SHOWING THE CONNECTION TO EXIST IN ALL DIRECTIONS ON A DISTANCE OF 2000 FEET.

A shaft was dug on Gatun hill where the spillway will be erected; another was dug on the location of the locks. Major Sibert gives figures which any engineer will find extremely discomforting, to say the least, as to the intensity of the flow through these fissures and the demonstrated connection between these fissures.

Mr. STEVENS: In pumping out the shaft at the spillway, what effect had it in lowering the level in the test holes along the dam?

Major SIBERT: There was one hole in the spillway that was artesian and about 640 feet away from the test pit. We made no systematic observation, but when we pumped out the test pit the flow stopped in the artesian hole, which showed the connection.

Mr. STEVENS: What was the remotest test pit from the shaft that was affected by the pumping-out process?

Major SIBERT: That was the only one observed. *We carried on systematic testing on that line at the locks. There the effect was noticed as far as 2,000 feet away.*

Mr. STEVENS: Was that test hole east or west or north or south of the shaft?

Major SIBERT: North of the shaft. *It lowered the water in the holes in every direction, but we had the longest line of holes in the direction of the lock, north to south.*

Mr. STEVENS: *That would indicate the connection of all the test pits with the shaft?*

Major SIBERT: *Yes, sir.*

Mr. STEVENS: That connection, you think, was through fissures or the waterlogged mass of material?

Major SIBERT: I think principally and almost entirely through small fissures.

Mr. STEVENS: Of course your pumping-out process hastened the flow?

Major SIBERT: Toward the pit—yes, sir.

Mr. STEVENS: You believe that when the dam is completed, as you now plan it, the underground flow will be practically eliminated, if not stopped?

Major SIBERT: You mean the dam or the lock?

Mr. STEVENS: Well, both.

Major SIBERT: *I think the underground flow under the locks will be increased somewhat when the lock is finished.*

Mr. STEVENS: *By reason of the head?*

Major SIBERT: *Yes, sir, by reason of the head.* If that water gets no outlet anywhere, I do not see how it can do any harm. It has been traveling

that way for centuries through these crevices. If it cannot get any outlet nearer than its present outlet, which is undoubtedly in the sea, the distance will be so great that the head will be so reduced, as it has been for ages past, that there can be no enlargements of the fissures. If it has an outlet, I would expect some scour, as has been seen in the test pit dug at the locks in the soft sandstone of the black variety.

Mr. STEVENS: *What was the rapidity of the flow in the test pit?*

Major SIBERT: *We got, I think, between 38,000 and 40,000 gallons per day.*

Mr. STEVENS: What was the diameter of it?

Major SIBERT: About 6 feet square—maybe a little larger; big enough to go into and to excavate by hand.

Mr. STEVENS: With the method of cut-off of the underground flow, due to a head of 85 feet, as described by Major Harding, will you have reduced the underground flow to a point where it would not endanger the foundations of your locks?

Major SIBERT: *Personally, I do not think it practicable to cut off this flow entirely, because we do not know the depth of these fissures, and consequently we do not know for certain that we can keep the pressure of the lake from under our lock floors by the curtain wall.* I think the flow of water under the lock foundations would be diminished, but I do not feel certain that we would not get a head of water under the floors with this curtain wall.

THE AMOUNT OF WATER TO BE LOST THROUGH THE FISSURES OF THE HILLS CANNOT BE DETERMINED. "IT IS A CHANCE WE HAVE TO TAKE ON THE PROPOSITION," SAYS MAJOR SIBERT.

To operate the lock canal with a dam at Gatun the preservation of all the waters brought by the Chagres and its tributaries is necessary in the strictest degree of the word.

If not one drop of water is lost by going to the sea the maximum traffic the canal can serve will be between 40 and 67 million tons annually according to the future average size of ships (an average size of 3,000 tons, say the actual average of the Suez Canal, corresponds to 40,000,000 tons and an average size of 5,000 tons to 67,000,000 tons).

To what figures will this maximum be lowered if the fissurated hills allow a part of the water stored to go to the sea? This is a matter of the greatest moment. The loss will take place. It is established. How much water will be lost? Nothing can determine it. And the very life of the canal depends upon it!

Under a head of 35 feet a little hole about six feet square has received from the fissurated ground 38 to 40 thousand gallons of water in 24 hours. This is about one forty thousandth part of the maximum supply of water that will be available for lockages in the dryest years, if not one drop of water goes to the sea except through the locks.

What will such a ground draw from the water reserve in the lake and send unused to the sea, with a head twice and a half greater, when the same ground will be in contact with the lake on many miles?

What will become of the loss of water through the fissures after a few years, when the rapidity of the current will have enlarged them by disintegrating the soft argillaceous sandstone upon which the water will run?

These are questions which cannot be dismissed as generated by an absurd scare, as Major Harding did before the Congressional Committee. These are questions which cannot be dismissed either "as a risk to be taken," as Major Sibert did before the same committee, as will be seen hereafter.

These questions involve the fate of the canal itself. If the Gatun hills are a sieve there will be no lake and if there is no lake there will be no canal after ten years' work after nearly $400,000,000 expenses.

These questions must be answered, they should be one of the principal preoccupations of the authorities.—CAVEANT CONSULES!

MR. STEVENS: Now, there are two saddles in the surrounding hills. Have you made any examination of these?

MAJOR SIBERT: Only from borings that have been made. Some of these hills are not close. One saddle is quite close, but not the one on the Trinidad?

MR. STEVENS: What is the height of that saddle above the lake level?

MAJOR SIBERT: For a considerable distance it is only a few feet.

MR. STEVENS: That would be soft earth, would it not?

MAJOR SIBERT: Earth and underlying material. It would be necessary to increase the height of that saddle.

MR. STEVENS: Has there been any boring in these saddles?

MAJOR SIBERT: An attempt was made in the beginning to make a spillway there instead of through the dam, but the underlying rock bottom was not of sufficient hardness to justify this.

MR. STEVENS: But the material was safe enough in your judgment to prevent any seepage in that direction?

MAJOR SIBERT: *Well, I do not know very much about that. I did not make any experiments in that direction.*

THE CHAIRMAN: Has any other gentleman any questions to ask?

MR. HUBBARD: I understand you to say, Major, that it is perfectly feasible to build this structure so that it will be safe, and that the floors can be constructed so as to prevent the upward pressure of water through the lock floors?

MAJOR SIBERT: That is my opinion. *Major Harding thinks that by building a curtain wall you will cut off the flow, but I differ with him there.*

MR. HUBBARD: You see no value in the curtain wall, then; you do not think it will cut off the flow?

MAJOR SIBERT: Well, I think it will not cut off the flow entirely.

MR. HUBBARD: Your statement was that the safety of the structure was conditioned on the floor being so constructed as to prevent water flowing through the floors?

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MAJOR SIBERT: I feel that the locks and dams can be built. There is some chance of danger in the Gatun dam foundation, but I do not think it is material enough to constitute an obstacle. It is in the range of possibility that some slips might happen, but whether it is in the range of probability or not, I do not think it is. That is, the slipping of the underlying material of the Gatun dam. That, to my mind, is the only weak point in the scheme, if there is a weak point. *As to the water supply of the lake; the question of seepage loss, not under the Gatun dam, but through the hills around it, that is a question we can only guess at.*

THE CHAIRMAN: Has there been no such explanation made as will enable you to say that after your work has been accomplished, and you have got your 85 feet of head, that all that may not be destroyed by the escape of these impounded waters by fissures you do not know anything about?

MAJOR SIBERT: We know it will not escape over any low places in the surrounding hills, but *we do not know with any great degree of definiteness the character of the rock and of the material constituting the rim of the lake.*

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MR. HUBBARD: That is, if you were set to execute a piece of work according to somebody else's plan, and had come to the conclusion that it could not be carried out, there would be a way to make it known with propriety to some one?

MAJOR SIBERT: I would not build a thing I did not think would stay there, unless I had notified some one in higher authority than myself of my fears, and this higher authority assumed responsibility for the plan.

MR. HUBBARD: Have you ever felt such a desire to make a report?

MAJOR SIBERT: I have always had confidence in the Gatun dam, and these difficulties, which are not serious, which we are encountering now are the only things that have happened to throw any discredit on the scheme, and that is entirely in the foundation. I have not had sufficient data to form any definite conclusion as to loss of water by seepage in this lake, and that is a question I have no thorough way of investigating; *it is a chance we have to take on the proposition.*

MR. STEVENS: I do not know if it is serious or not; it would be if you could not hold the lake.

MAJOR SIBERT: *It is an unknown field to me.*

Erratum.

[An error made in composing this pamphlet has caused the following chapter, which should have been printed on pages 46 and following to be omitted. It is not perhaps to be regretted that it was placed apart on account of its importance.]

Why was the Straits of Panama Objected to by the International Consulting Board in 1906?

It is easy to see from the records that this rejection was purely based on the false assumption that the transformation of rock into dredgable ground would cost $2.35 when it has been officially demonstrated since to cost eleven times less in the Suez canal and eighteen times less in the Manchester canal.

The cost at Panama of that transformation would be certainly inferior to the cost at Manchester, not only on account of the saving in expense due to the gratuitous mechanical power given by the falls of the Chagres, but also and principally on account of the extremely soft character of the greater part of the Isthmian rocks.

To demonstrate this important fact it is sufficient to quote what can be found on page 93 of the report of the Isthmian Canal Commission of November 16, 1901. This report cannot be accused of any bias in favor of Panama because it recommended the Nicaragua solution.

Speaking of the central mass of the Isthmus where the greatest quantity of hard material is accumulated, the report says: "The summit cut is 7.91 miles long from the Obispo "gates to the Pedro Miguel locks. * * * There is a little "very hard rock at the eastern end of this section and the west- "ern two miles are in ordinary materials. The remainder con- "sists *of a hard indurated clay* with some softer material at "the top and some strata and dikes of hard rock. In fixing "the price *it has been rated as soft rock, but it must be given*

"*slopes equivalent to those in earth* * * * probably *nine-* "*tenths of the material would naturally be classed as hard clay* "*of stable character.*"

This description will better than anything else give a correct idea of the general character of the isthmian rocks. Except for a few points there is no hard rock. The bulk of the hard material encountered is a volcanic hard clay very similar to the soft rock met in certain Japanese harbors, where the cost of the transformation into dredgable matter is still much lower than the Manchester canal figure. In these Japanese harbours it approximates two cents a cubic yard, and, therefore, is one hundred and seventeen times cheaper than the Consulting Board determined.

Another description of the nature of the Culebra cut was given by Mr. Stevens, then Chief Engineer of the Canal, to the Consulting Board in 1905 and can be found in Appendix J of their Report (page 286). Though worded differently it absolutely confirms the description of the Isthmian Canal Commission reproduced hereabove.

Mr. Stevens * * * "*I regard the whole Culebra cut as* "*a soft-rock proposition.* While it is true that a shovel "would pick up some of it without blasting, you can do it all "much more economically to shoot it. * * * As far as I "have been able to observe, you can classify the Culebra "above as red clay overlying argillaceous schists, with hard "igneous trap thrown up through it. A great many borings "have been made. It is a mixed conglomerate mass."

Mr. Stevens further explains what is the general character, as to hardness, of the Culebra Cut on page 289 of same report.

Mr. Parsons: Taking the Culebra Cut from Obispo to Paraiso, averaging it all through, you would call it a soft-rock proposition?

Mr. Stevens: *What I would call hard trap is not large,* therefore to average it right through it is a shooting proposition. *Any argillaceous schist is always soft.*

Another estimation of the nature of the ground of the Isthmus was made in 1905 by the Isthmian Canal Commission for the sea level project which they submitted to the International Consulting Board. It was exceedingly prudent and even pessimistic. They based their estimates on one fourth loose ground, one fourth rock, one half soft rock.

If we suppose the dredges employed will be bucket chain dredgers of the french type, the bucket capacity being one cubic yard and a half, a daily (24 hours) practical excavation of 10,000 cubic yards may be confidently expected for each dredge. Therefore twenty dredges in a month of 25 days will excavate 5,000,000 cubic yards say 60,000,000 cubic yards a year and 600,000,000 cubic yards or the entire cube of the "Straits of Panama" within ten years.

Admitting for the real rock the lesser advantageous proportion of one fourth instead of one tenth we see that 15 rock breakers will be necessary for each dredge. (10 breaking 250 cubic yards each daily of real rock and 5 breaking 1,000 cubic yards of soft rock.)

Mr. Kellennec, chief engineer of the Suez Canal, in his report on rock dredging at Suez to the conference of Civil Engineers in London, 1907 (Transactions of Section II.) says that the average number of blows had been 7.1 per cubic meter and the number of actual blows delivered in one hour 115 (after eliminating the loss due to the passage of ships in the narrow Suez Canal). This gives 22 cubic yards per hour or 528 cubic yards daily.

This shows how conservative is the figure of 240 cubic yards I just admitted for the real rock in Panama, it allows for an average hardness making necessary twice more blows than at Suez. It corresponds to the hardness of the gneiss excavated in the outer bay of Brest harbour where 15 blows were found necessary per cubic meter as an average.

Mr. Kellennec further states that certain parts of the rock was extremely hard and sometimes but rarely made forty

blows necessary, but that on the other hand *one blow for soft rock* was sufficient to shatter one cubic meter.

In the inner harbour of Brest the hardest and most compact silica was found which required 60 blows.

These figures demonstrate that the concussion system does never find rock of sufficient hardness to stop its use.

Of course the number of blows varies with the hardness of the material.

Very misleading information might cast a doubt on the efficiency and the cheapness of the method if taken at a given point where the hardness of rock is excessive and where there are not a sufficient quantity of rock breakers at work to keep a powerful dredge busy. Under such circumstances the total price might be unexpectedly high.

But this has no bearing on the subject now examined. Here the question is one of average as it was on the Suez Canal, as it was on the Manchester Ship Canal. In both these cases in spite of the very hard rock sometimes encountered the average cost was twenty cents and twelve and a half cents respectively. On the Panama Canal there is not the slightest doubt that the average will be lower than is the case of Suez and even of Manchester, because even the hardest rocks cannot be compared to the compact silica of the inner Brest harbour, and because they are in infinitesimal quantity. The great bulk of the real rock is not hard and the soft rock is more a hard earth than a soft rock, it is a dry, stiff clay which breaks and disintegrates very easily at the slightest shock.

The "Straits of Panama" Formerly a Chimera Now a Practical and Tangible Reality—the Most Economic of Plans.

The excavation of the 600,000,000 cubic yards would be chimerical if it were to be made in the dry, as the sponsors of the tide locked sea level canal propose to excavate the larger

part of their 230,000,000 cubic yards. It would be chimeral in the wet system if the excavation of the rock below water should cost $4.75 a cubic yard, as the Isthmian Canal Commission erroneously believed in 1901. It would be chimerical also in the wet system, if it should cost $2.50 as the Consulting Board erroneously believed in 1906.

It is the most economic and at the same time the most perfect of all the plans if the removal of one cubic yard of material is brought by actual practical methods down to sixteen cents on an average.

There are enough official proofs of such a fact to justify an entire reconsideration of this capital question. If unbiased and free minded engineer officers of the army, having had no anterior connection with the plans under discussion, should be sent to investigate first the nature of the rock on the Isthmus and then to study in France, England, Egypt and Japan the actual improved methods of dredging soft and hard material the cloud would be soon dissipated. The supposed chimera would become a real tangible thing and the United States, the trustees of humanity in the construction of the great international waterway, would give to the World what it wants, what it is possible now and easy to obtain : "the Straits of Panama."

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